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THE MINNESOTA SEASIDE STATION.

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WHEN, in 1900, a tract of land on the Straits of Fuca was offered for the uses of a marine station to be operated in connection with the University of Minnesota, the transfer was made and the construction of a laboratory-camp begun. Previous and full information concerning the site had been received. It had been personally examined by a member of the University staff and had been highly commended. Being at the entrance of the Straits it was easily accessible to the Sound and to the open sea, while its littoral fauna and flora were known to be uncommonly interesting and rich both in species and individuals. One difficulty existed: there was no road from Port Renfrew to the laboratory site—a distance of about three miles. Consequently the whole matter was laid before the British Columbian Parliament then in session at Victoria, and through the assistance of the honorable members from the districts of Esquimalt and San Juan, with the approval of H. M. Commissioner of Works, a grant was obtained for a suitable road, work upon which was in progress during the summer of 1901.

In the initial movements incident to the establishment of the Station many Victorians were both interested and effective. From Sir Henri Joly de Lotbiniere, Lieutenant-Governor of the Province, to the humblest citizen there was received only the most uniform and delightful courtesy. To acknowledge so many kindnesses is indeed a pleasure, and to the members of the Government and of the Natural History Society of Victoria, and to all others who were of assistance sincere appreciation and thanks are due.

FIG. 1. BUILDINGS OF MINNESOTA SEASIDE STATION AS SEEN ACROSS STATION COVE. THE BUILDINGS FACE NEARLY SOUTH.

FIG. 2. GROUP OF STUDENTS HOLDING AN EXTENDED SPECIMEN OF THE GIANT KELP, NEREOCYSTIS PRIAPUS. JUST OFF SHORE A BED OF THIS KELP IS SHOWN.

The usefulness of a marine station on the Pacific as an adjunct to the laboratories of a university located far inland naturally needs no proclamation. During more than two decades, experience gained by American students at such points as Beaufort, Woods Holl, Cold Spring Harbor, Pacific Grove and elsewhere has demonstrated that the broadest and best foundations for a knowledge of morphology can not be laid without the assistance of instruction and research at the shore. More and more must the recognition of this fact become general, and with each succeeding year the number of serious students at the ocean-side and facilities for their work must increase and improve. That there should be stations upon both the eastern and the western coasts is imperative, and each will come to have its peculiar excellences and will develop its special lines of work. The eastern station has the advantages of accessibility while the western enjoys those of remoteness. At the laboratory on the eastern shore one may perhaps look for more conveniences and refinements; at that on the western coast one may expect more novelty and a greater openness and freedom of opportunity. To the student in the far west nothing can be more helpful than contact with the east; for the student in the east nothing is more to be desired than a sojourn in the west. Apparently, then, stations upon the Atlantic and Pacific coasts are alike desirable, and each with its own field of usefulness may be the complement of the other. Not only does the truth of this appear from the point of view of sound and broad instruction, but quite as impressively in connection with research. The living organisms of the two great oceans are by no means identical. To the student who turns his face from the Atlantic to the Pacific feeling that the New England or New Jersey shore has become somewhat trite and habitual, there is a fresh inspiration and enthusiasm to be derived from the coast of California or Vancouver.

One very distinct advantage enjoyed by a west coast station is the surpassing interest of the journey by which it is reached from a mid-continental or eastern point. While the tourist from Chicago to New York or Boston finds the journey swift and luxurious, he is passing through a relatively monotonous and uninteresting country. It is quite otherwise with the traveler from Minneapolis to Port Renfrew. In estimating the advantages of the Minnesota Seaside Station as an outpost of natural science and nature-study, there must certainly be taken into account not only its own immediate environment, but the route by which it is most conveniently reached from an eastern city. The journey over the Canadian Pacific, made in special cars and with the privilege of stopping at will, cannot be paralleled elsewhere on the continent. From the forest of central Minnesota the train speeds on through illimitable wheat-fields billowing and shimmering from horizon to horizon. It climbs from the valley of the Red river out upon the vast and lonely

plains of Assiniboia and swings westward, hour after hour, over the silent ranges furrowed everywhere by unnumbered feet of the departed herd. It rises to the foothills beyond Calgary and sights the white wall of the Rocky mountains a hundred miles away. It plunges through the Gap at Canmore, ascends the valley of the Bow between colossal peaks, crosses the continental divide at Laggan, drops down the canyon beside a foaming torrent to the mountain-girt valley of the Columbia, rises again mile after mile into the icy air of Rogers Pass amid the glaciers of the Selkirk summits and finds its way with the rushing waters of the

FIG. 3. FOOT OF THE GREAT GLACIER OF THE SELKIRKS.

Illicillewaet down to the Columbia again at Revelstoke. It hurries through echoing valleys, beside enchanting lakes, across ridges and chasms into the desert along the Thompson. It enters the historic valley of the Fraser and underneath frowning cliffs creeps down the reverberant gorge to the wonderful amphitheaters of Yale and Hope and finally reaches Vancouver and the sea. Then come the steamer voyages through the Straits of Georgia to Victoria and through the Straits of Fuca to Port Renfrew, and at last the invigorating walk through the forest or sturdy pull along the shore. To the lover of nature as well as to the serious student of ecology or plant distribution there is perhaps nowhere in the world a more inspiring and instructive journey of two thousand miles than this. It gives an opportunity of becoming

acquainted with the forests, the prairies, the plains, the foot-hills, the mountains, the glaciers, the deserts and the sea.

At such points as Lake Louise, where the mountain scenery is indescribably grand, there is an unequaled field for the study of talus-vegetation, the influence of the snow-line and the avalanche upon plant distribution and the characteristic population of mountain-park and meadow. Here one comes close to the wild life of the peaks, and far above the lake one may see the goats grazing upon their inaccessible crags or one may sometimes hear the roar of a grizzly rising distinct

FIG. 4. VIEW ON LAKE LOUISE SHOWING EFFECT OF SNOW SLIDES AND TALUS SLOPES ON THE DISTRIBUTION OF PLANTS.

above the clamor of the torrents. At Glacier the effect of ice-currents upon the growth and distribution of plants is most interestingly displayed. A series of photographs beginning just in front of the ice-mass and extending some hundreds of yards down the valley of the Illicillewaet shows at a glance how revegetation has proceeded, as the glacier has slowly and regularly retreated.

The exact situation of the Minnesota Seaside Station is in a little cove at the entrance of the Straits of Fuca, nearly opposite Cape Flattery, just outside the picturesque harbor of Port Renfrew and about sixty miles north of the city of Victoria. The west shore of Vancouver island is described in the old books of travel as a 'stern and rock-bound coast,' and it is indeed a perilous one for navigation. During much of

the year there is mist and fog to conceal the reefs and ledges and it has been the scene of many a tragedy of the sea since the old days of Drake and Ferrelo and the quest for the Northwest Passage. If the fog hangs low one may perhaps hear in the offing the sullen note of an Oriental liner as she feels her way into the Straits of Fuca, or if the skies are

FIG. 5. A VIEW OF THE SHORE AT LOW TIDE JUST IN FRONT OF THE SEASIDE STATION.

clear one may look across the water to the blue shores of Washington, indented by Neah and Clallam bays and prolonged westward into the ocean to the rock upon which stands Cape Flattery light. To the left rise the far-shining peaks of the Olympic mountains and, with a binocu-

FIG. 6. THE OLYMPIC MOUNTAINS AS SEEN ACROSS THE STRAITS OF FUCA, FROM THE NEIGHBORHOOD OF THE RACE ROCKS.

lar, glaciers can be seen upon their untrodden summits. When the Straits are flashing with the breeze, the picture of ocean, shore, forest and mountain is one of the most beautiful in the world, rivaling the

bay of Naples or the Adriatic and almost equaling the matchless Peruvian coast and the sea-front of Ecuador.

The log buildings of the Station stand in a small clearing and have an outlook upon the Straits and upon the Pacific. With the forest behind and the ocean in front their situation is as perfect scenically as it is for the purposes of science. Miles of tide-pools, reefs and kelp-covered rocks are easily accessible along the water front, while landward the hills rise to a height of nearly 3,000 feet. Four miles back are the mouths of the San Juan and Gordon rivers, both of which flow into Renfrew port and may be utilized as canoe routes towards the lakes and mountains of the interior. Over the whole country side spreads the primeval and well-nigh impenetrable forest of Vancouver with its gnarled yews, enormous cedars and towering spruces. On each side of

FIG. 7. 'THE FORMALOSE CLUB.' THE ALGAE DRAPED OVER THE LOGS ARE EGREGIA AND NEREOCYSTIS.

the Station buildings a little rivulet comes down from the hills and the waters of the two mingle on the rocks just below high-tide mark. Altogether, the opportunity for the study of marine and coastal botany and zoology is magnificent, and there is no good reason why it should not be possible to maintain a thoroughly well-equipped international marine station at the entrance to the waters of Puget Sound. The location is altogether admirable, rich and interesting, and practical work has begun.

FIG. 8. A COVE ON THE WEST COAST NEAR THE STATION SHOWING SALAL BUSHES, ENTEROMORPHA FORMATION AND A STRONG ZONE OF FUCUS EVANESCENS. THE TREES IN THE CENTER CARRY LARGE MASSES OF EPIPHYTIC MOSSES.

FIG. 9. KELP-COVERED ROCK SHOWING SPECIMENS OF EGREGIA, ALARIA AND HALOSACCION IN CHARACTERISTIC ATTITUDES. PHYLLOSPADIX SCOULERI APPEARS IN THE FOREGROUND.

At present the buildings of the Station number two and comprise a small house, 25 by 12 feet, on the shore, with a larger building, 60 by 25 feet, in the rear and on the higher ground. A third building is to be erected during the winter. Last summer, when a party of thirty-three went west from Minneapolis, it was apparent that the buildings would be inconveniently crowded, but by devoting half of the large living room to laboratory purposes it was possible to accommodate all who desired to work. The small house was used principally for microscopic work and for preservation of anatomical material. It received the name of the 'Formalose Club' from some ingenious members of the party. The large house is two stories in height and arranged for general camp purposes. Below, a transverse hallway divides the kitchen and storeroom from the

FIG. 10. FIELD OF ENDOCLADIA MURICATA ON SCHISTOSE ROCK TOGETHER WITH MUSSELS AND BARNACLES.

dining and living room. The latter with its large fireplace at the end and its festoons of flags and bunting in the University colors proved to be attractive and cheerful. Above, two large bunk rooms, one for men and one for women, afford the comforts of balsam beds to the weary, after the day's work is done.

Station equipment did not present a very serious problem during the first season. Most of the party preferred to devote their energies to the collection of material. However, some twelve or fifteen microscopes were in use, and both the small library and the store of chemicals and glassware were daily drawn upon.

In view of the many novel varieties and curious habits of the seaweeds they were the principal objects of study during the season of 1901.

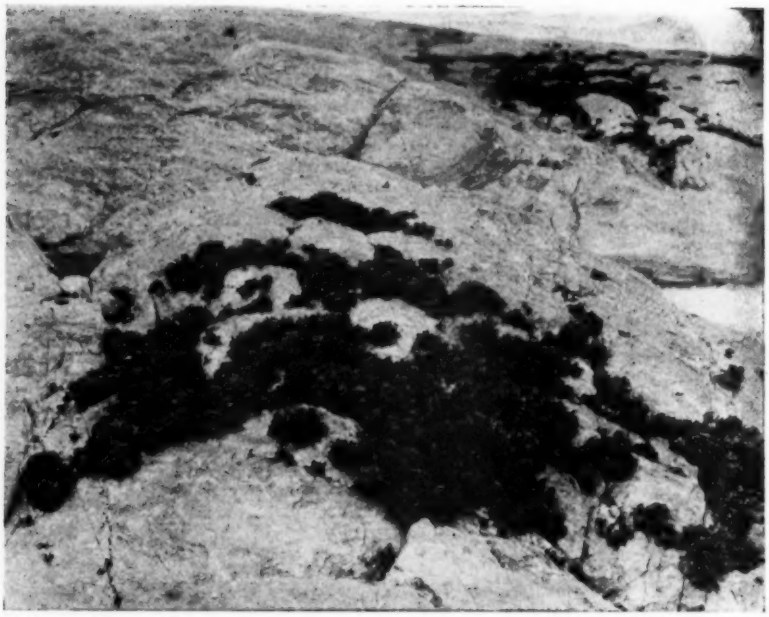

FIG. 11. A GROUP OF PELVETIA, A CHARACTERISTIC HIGH-TIDE WRACK OF THE WEST COAST.

FIG. 12. THE UPPER, OR HEDOPHYLLUM ZONE, OF THE KELP FORMATION IS SHOWN IN THE FOREGROUND. IN THE MIDDLE DISTANCE ALARIA AND LAMINARIA BONGARDIANA WITH PLANTS OF EGREGIA ARE THE ABUNDANT FORMS.

Not only did they prove of unusual taxonomic interest—some entirely new species being collected—but also well worthy of careful ecological research. Their zonal distribution, formation groups and choice of special substrata were noted, together with their behavior at different stages of the tide. Often very sharp lines of demarcation between different algal societies were exhibited. In Figure 8 an excellent example is reproduced. At the rear, near the center, is seen the characteristic fringe of salal (Gaultheria shallon) in front of which Enteromorpha colonies are established upon the flat sandstone. In the foreground appears a sharp zone of wrack (Fucus evanescens). In this view there is also shown some of the unusually vigorous epiphytic moss-vegetation so

FIG. 13. IN THE FOREGROUND ARE SEEN PHYLLOSPADIX SCOULERI, LAMINARIA BONGARDIANA AND LESSONIA LITTORALIS, THE LATTER BEING A CHARACTERISTIC SURGE PLANT OF THE COAST.

abundantly represented on Vancouver island. Another very distinct instance of zonal distribution is shown in Figure 9, the photograph having been taken at low tide. In the foreground the slender leaves of a marine angiosperm (Phyllospadix scouleri) are seen, spread over which are fronds of Egregia, one of the most notable of the west coast kelps. The sides of the dome-shaped rock are draped with kelp, principally Egregia and Alaria, while the top is covered with a fairly uniform and copious growth of the alga which has passed under the name of Halosaccion hydrophora, but concerning which it is possible that an error has been made by American phycologists.

Under other topographic conditions the zonal distribution is not so

evident, and in Figure 10 is shown an arrangement of algae and animals upon a much creviced slate. Barnacles of two distinct types and mussels, mingled with a growth of Endocladia muricata, appear in this

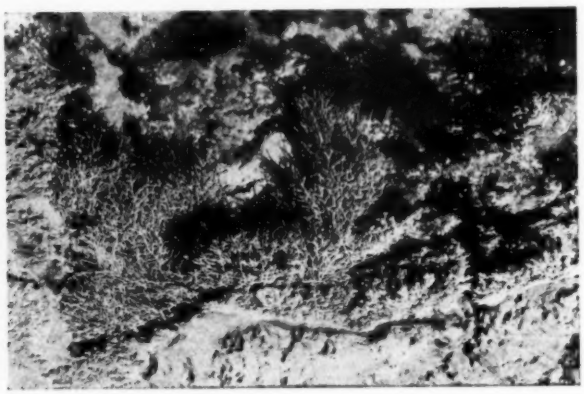

FIG. 14. CORALLINACEAE AT THE EDGE OF A TIDE-POOL, ON THE RIGHT AMPHIROA AND ON THE LEFT CORALLINA.

view, but the general grouping is less clearly concentric. Nevertheless the Endocladia zone is pretty well defined as a mid-tide algal society and sometimes shows sharp demarcation when favorably situated for a pure growth.

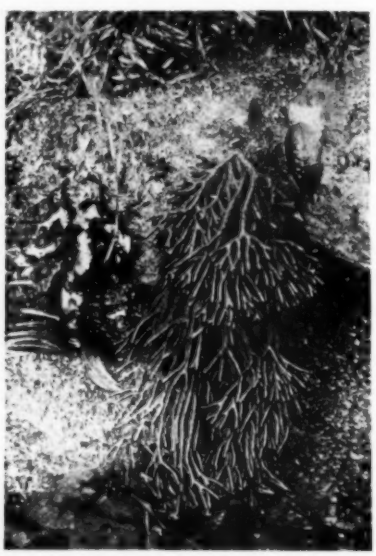

FIG. 15. A PLANT OF CODIUM MUCRONATUM CALIFORNICUM, A CHARACTERISTIC SIPHONACAEOUS ALGA OF THE TIDE-POOLS.

Among the high-tide algae—those occupying the upper zones—Pelvetia is an interesting form. It occurs at the same levels adopted by

Fucus, of which it is taxonomically an ally, and often produces considerable beds, though not everywhere abundant like the Fucus. In Figure 11 a group of Pelvetia is shown and its habit can easily be recognized.

FIG. 16. A FROND OF DESMARESTIA LIGULATA HERBACEA TAKEN FROM THE WASH AFTER A STORM.

Of the low-tide algae there is not only a characteristic segregation relative to depth of water, but a careful selection of habits more or less exposed to the influence of the surf and surge. Quite a characteristic group of surf-plants including such kelps as Postelsia palmaeformis and one species of Alaria display themselves where the surf is strongest and seem to require the foaming water of the breakers for their best development. Below these in more sheltered places one finds Hedophyllum, Alaria and Egregia. Below Postelsia, but exposed to strong surge, grow the Lessonias, while Pterygophora seeks the bottom of the surge and Nereocystis anchors itself in still deeper water outside the line of breakers. In this outer zone, too, Macrocystis and Dictyoneuron seem to find their best opportunities for growth, while Costaria comes somewhat nearer shore. The latter is, however, commonly brought up with the Nereocystis holdfasts, when they are detached from the bottom. Figure 13 shows the exposure of surge-plants at low tide. On the right is Lessonia littoralis. In front is Laminaria bongardiana and on the left is Phyllospadix scouleri. The Lessonia, in particular, is beautifully adapted by its massive trunk and slender leaves to maintain its foothold in the surge and with Postelsia in the surf and Nereocystis in the deeper water shows in magnificent fashion the work-

FIG. 17. PLANT OF RHODOMELA FLOCCOSA TAKEN FROM THE WASH AND PHOTOGRAPHED IN A GLASS-BOTTOMED TANK.

ing out of the same structural type under slightly different adaptational conditions.

In the sheltered pot-holes where the motion of the water *en masse* is not possible and where the total movement is comparatively less violent, one finds an altogether different flora and fauna from that in evidence on exposed reefs. Figure 14, showing the edge of a tide-pool and penetrating below the surface of the clear liquid that fills it, presents a view of two genera of Corallinaceae—Amphiroa on the right and towards the center, and Corallina on the left. Below, suffering from slight refraction, may be identified the frond of Codium mucronatum cali-

FIG. 18. TRUNK OF A WEST COAST CEDAR SHOWING THE ABUNDANT EPIPHYTIC VEGETATION AND INDICATING THE CHARACTERISTIC LOMARIA FORMATION OF THE FOREST FLOOR.

fornicum. The latter alga, a somewhat characteristic inhabitant of the tide-pools, is shown exposed to the air in Figure 15. Its size may be judged by the leaves of Phyllospadix above and the Chiton clinging to the rock.

Some of the seaweeds of Port Renfrew were difficult to gather except from the wash. Here certain large forms such as Dictyoneuron, Desmarestia, Callymenia and others were particularly abundant. Figure 16

shows such a plant of Desmarestia ligulata herbacea, while Figure 17 is from a photograph made in a tank with glass bottom and shows a plant of Rhodomela floccosa.

The portraits of algae given will suffice to indicate the wealth of material awaiting study and research at the Minnesota Seaside Station. The interior country with its forest and mountains is scarcely less interesting than the shore. The botanist from the East is particularly impressed with the magnificent size of the trees, the luxuriance of the Lomaria formation of the forest-floor and the wealth of epiphytic and parasitic vegetation. The boughs of the trees are festooned with mosses

FIG. 19. MOSS-COVERED HEXENBESEN OF THE DWARF MISTLETOE ON HEMLOCK TREES NEAR PORT RENFREW.

and hepatics and their bark covered with lichens, ferns and small flowering plants. Figure 19 shows a typical colony of Polypodium scouleri upon coniferous bark and illustrates the prevalent epiphytism of ferns and mosses throughout the district. Figure 20 gives a view of mistletoe hexenbesen covered with moss and due to the action of the dwarf mistletoe, Razoumofskya pusilla. Numerous other parasitic plants are to be

found in the forest, notably Boschniakia strobilacea, a member of the broom-rape family and omnipresent upon the roots of the salal bush.

From the above it will be seen that the natural surroundings of the Minnesota Seaside Station are highly favorable for varied and productive research. The beginning that has been made has received encouragement from Canadian and American botanists, and it is possible that the modest camp on the Straits of Fuca may develop into a genuine marine laboratory with full equipment and a field of usefulness peculiarly its own. In any event it will doubtless serve as an objective point for more than one biological pilgrimage from the central-western states. During the season of 1901, when possibly the largest scientific party ever

FIG. 20. POLYPODIUM SCOULERI A COMMON FERN EPIPHYTE ON TREE TRUNKS.

conducted to so distant a point was enabled to spend a pleasant and profitable six weeks in the mountains and on the shore, representatives from several universities, colleges, normal schools and high schools were in attendance, one coming all the way from Tokyo. So successful an experiment as that of the summer just past will certainly justify the organization of other parties in years to come.

The illustrations in this paper are all from photographs by C. J. Hibbard, Esq., photographer of the Department of Botany in the University of Minnesota, with the exception of Figure 6, which is from a lantern slide by Flemming Bros., of Victoria, B. C.

ANTARCTIC EXPLORATION.

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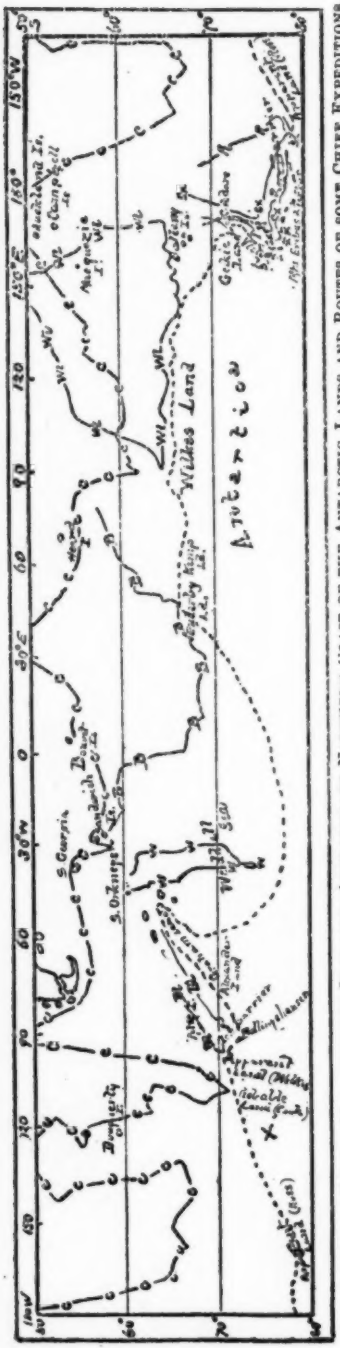
I. *The Search for the 'Terra Australis.'*

THE search for the supposed great southern continent roused interest in the South Polar area, even earlier than the commercial need for the Northeast or Northwest Passage directed the attention of the European nations to the Arctic seas. Long before Hudson had started the northern whale fishery, or Barents had discovered Spitzbergen, or Willoughby had set out on that 'new and strange navigation,' which, according to Milton, was intended to save England from the commercial ruin threatened by foreign competition, Arabian, Dutch and Spanish sailors had searched for a continent in the great southern sea.

Belief in the existence of this 'Terra Australis' dates from the time of the earliest classical geographies. They regarded it as a corollary of the spherical shape of the earth; for it was thought that terrestrial equilibrium could only be maintained by two land masses acting as counterpoises to the land of the old world. The existence of America was therefore predicted as the necessary western antipodes, and a great southern continent was assumed as the southern antipodes. The land that Ptolemy represented as connecting Africa and southeastern Asia and closing the Indian Ocean as a Mediterranean Sea, was regarded as part of the northern shore of this southern continent. Faith in this 'Terra Australis' has survived in spite of the repeated failures to prove its existence; for more than two and twenty centuries the supposed limits of this land have receded as geographical research advanced southward. One of the geographical results of the Indian expedition of Alexander the Great was the separation of Ceylon from the southern continent. Ptolemy's land connection between southern Africa and eastern Asia was pushed backward by the Arabian sailors who reached Australia. Confirmation of the theory was however claimed by the discovery of Terra del Fuego and Australia; but the passage of Drake's Straits and Tasman's voyage along the southern coast of Australia showed that both areas were bounded southward by the sea. Then it was asserted that New Zealand was part of the southern continent, and de Bougainville was sent in 1763 to discover colonizable parts of it, so that France might replace her lost American possessions by new settlements in the south. The French expedition, however, was disappointed


Wilkes Land
Victoria Land
Ross Sea
Ross Barrier
Balleny Is.
Scott Is.
Admiralty Mts.
Adelie Land
Graham Land
Weddell Sea
Enderby Land
Kemp Land
Mawson Land
Princess Elizabeth Land
Queen Mary Land
Kaiser Wilhelm II Land
Queen Maud Land
Coats Land
Coats Land
Graham Land
Alexander I. Land
Ellsworth Land
Marie Byrd Land
Edward VII Land
Victoria Land
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Kemp Land
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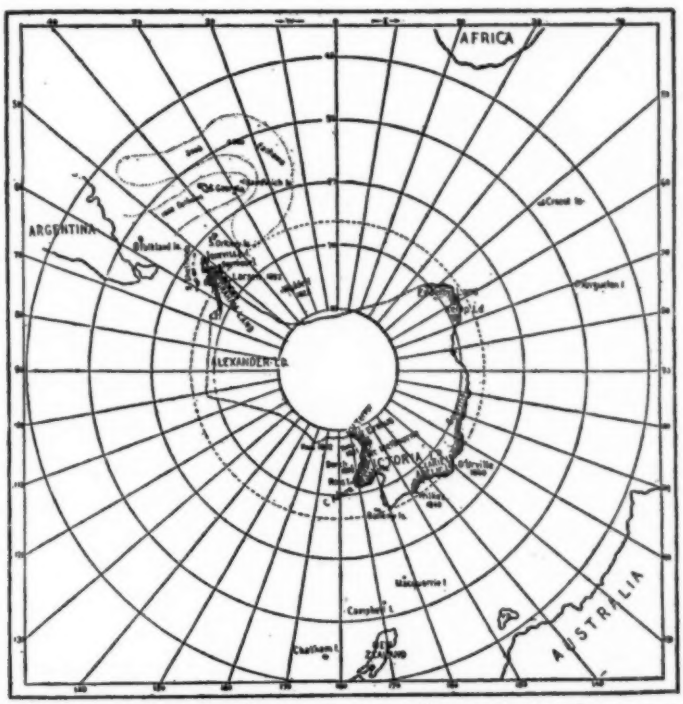
Queen Mary Land
Kaiser Wilhelm II Land
Queen Maud

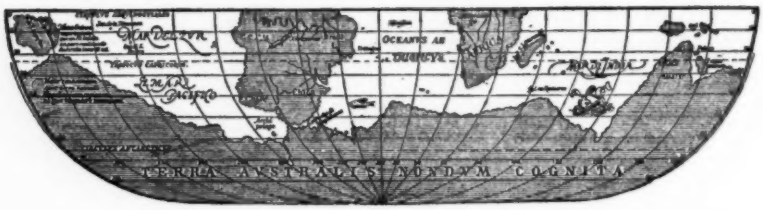
ments. He circumnavigated the south polar region, and reached latitudes which in some parts of his circuit have not yet been passed. Cook's magnificent results were all the more remarkable because of his distaste of the work. He described the sea as 'so pestered with ice,' and the lands as having 'an inexpressibly horrid aspect, and though he saw the beauty of the icebergs he regarded them with a 'mind filled with horror.' While so many coasts were uncharted and so many seas were unsurveyed Cook thought it a preposterous waste of time to hunt for a land, which, even if it existed, would be absolutely useless to his or to several succeeding generations. At times Cook was so impressed by the worthless nature of the Antarctic lands, that he believed they would be severely let alone when men heard his report of them and that they are uninhabited, uninhabitable and tradeless. If any one go further south than I have been, said Cook, 'I shall not envy him the honor of the discovery, but I will be bold to say that the world will not be benefited by it.'



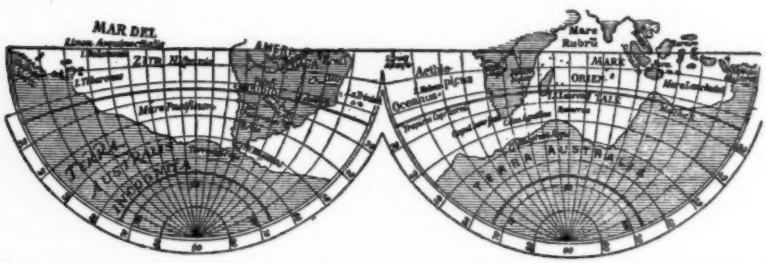
SKETCH MAP OF THE ANTARCTIC TRACT, GIVING THE MORE IMPORTANT POINTS THAT HAVE BEEN NAMED BY NAVIGATORS.

All through Cook's journal we feel his irritation at having been sent on a mission which he regarded as a waste of his time and powers. He was comforted by the thought that he had, however, finally shown

that there is no room for the Terra Australis of classical and mediaeval cartographers. Nevertheless he was convinced that there was a nucleus of land in the middle of the ice-pestered sea, for he accepted the view that thick ice is not formed on the open sea. This view was based on the argument advanced by de Brosses in 1756, that as sea ice is sweet it must be formed on land, until in 1776 Nairsie explained that ice formed by the freezing of the sea water is fresh because the salt is extruded as brine. Cook, however, was no doubt quite correct in the view that the great flat-topped Antarctic bergs could not be formed by the direct freezing of the open sea, but must have been formed on land.



TERRA AUSTRALIS (THEATRUM ORBIS TERRARUM, 1571).



TERRA AUSTRALIS, AFTER MERCATOR (ATLAS MINOR, EX-OFFICINA JOANNIS JANSSONII, 1648).

Hence in spite of the comparatively narrow limits within which Cook's work had restricted the possible existence of Antarctic land, the search for it was still continued. Islands were found south of the Atlantic; but it was not till 1840 that any extensive land area was discovered south of the Pacific and Indian Oceans. Then almost simultaneously a French expedition under Dumont d'Urville, and the American expedition under Wilkes discovered the long coast line or chain of islands known as Wilkes Land.

Wilkes' work was not only important because he traced this coast line at intervals for 60 degrees of longitude; but the geological collections made by his expedition showed that the land is formed of granites, massive sandstones and other rocks of continental types.

Two years later the extension of Wilkes Land to the east and the south was proved by the famous expedition of Sir James Clark Ross, which circumnavigated the Antarctic area and passed all previous

records by reaching the latitude of 78°. On his own lines Ross's work was magnificent. His magnetic survey has not been equalled in the Antarctic; his southern record was not passed until 1900; his discovery of Victoria Land and Mounts Erebus and Terror were geographical results of high importance. But Ross's range of interest was narrow; he did not land on the main land he discovered, and would not let his doctor, McCormick; he advanced erroneous theories of oceanic circulation, assigned wrong temperatures to the sea water, owing to misunderstanding his thermometers; he told us practically nothing of the geology of the Antarctic lands, for the few pebbles he brought back were neglected until they were recently unearthed and described by Mr. Prior.

After the voyage of Ross there was a long interval before serious work in the Antarctic was renewed. Sealers and whalers made minor geographical discoveries, and the voyage of the 'Challenger' in 1874 showed that the Antarctic sea is full of scientific interest. But it was not until 1885 and 1886 that the papers of Professor G. Neumayer, now of Hamburg, and formerly director of the Flagstaff Observatory at Melbourne, and of Sir John Murray roused fresh interest in Antarctic research. Since then the voyages of some Dundee and Norwegian sealers, of the 'Antarctic' and 'Southern Cross' in Victoria Land and the Ross Sea, and of the 'Belgica' to the south of the Atlantic have made important additions to our Antarctic knowledge.

II. *The Four Antarctic Expeditions.*

Now, in the year 1901, four expeditions are starting for the Antarctic: an English expedition under Commander R. F. Scott, R. N., in the 'Discovery,' with Mr. G. R. Murray, F.R.S., as head of the civilian scientific staff; a German expedition under Professor E. von Drygalski in the 'Gauss'; a Swedish expedition under Dr. Otto Nordenskjöld in the 'Antarctic,' and a Scotch expedition under Mr. W. S. Bruce.

The four expeditions will work as far as possible on a common plan, but in different areas. The 'Discovery' will start from New Zealand and go thence into the Ross Sea, which will be its central field of work. The German expedition will go south from Kerguelen to the western end of Wilkes Land, geographically the least known part of the Antarctic; its route will depend on the geography of the area, but the idea is to work southwestward toward the Weddell Sea, south of the Atlantic. The Swedish and Scotch expeditions both go to the South Atlantic.

The work of these expeditions will depend primarily on the geographical character of their fields of operation. The Antarctic area includes three main geographical divisions, (1) Wilkes and Victoria

Lands; (2) the division south of the Pacific from Ross's Sea to Alexander Land; (3) the Graham Land with its associated archipelagoes and the Weddell Sea that separates it from the western end of Wilkes Land.

As the first essential to the scientific investigation of a country is some acquaintance with its general topography, the primary factor in determining the work of the expeditions is the grade of our geographical knowledge of their fields of operations.

Geographical knowledge of the Antarctic is at present on two grades; in some areas the pioneer exploration has been done as far as concerns work at sea; of other areas we know nothing. Our knowledge is of the first grade in respect to only two or three areas; they are Graham Land with its associated islands and the coast of Victoria Land with the adjacent Ross Sea; perhaps we should also include in this category the northern shore of Wilkes Land, though it is known only at intervals and one of its most important areas, the angle between it and Victoria Land, is quite unknown. The rest of the Antarctic regions is on the second grade; the shores of the Weddell Sea have never been sighted; the western termination of Wilkes Land is quite hypothetical; speculations as to the area to the south of the Pacific are dependent on general considerations and the interpretation of a couple of distant and imperfectly recorded views.

Accordingly the plan of operations of each expedition should be dependent on the extent of our geographical knowledge of its field of operations. The English expedition has the advantage of a well-known entry into its central area, in which the most fruitful work will be scientific observations taken with the highest degree of accuracy and in the fullest detail. For pioneer geographical work it will be dependent on sledge expeditions inland, and at sea on how far it can push eastward from the Ross Sea into the southern Pacific.

The German expedition on the other hand goes into the region of which our ignorance is most complete. Its first work will therefore be pioneer geographical exploration, on the basis of which its expert scientific staff can found the observations that will be made concurrently. The expedition starts from the French island of Kerguelen where a base station and observatory have been established. Thence the 'Gauss' will sail due southward toward the supposed western end of Wilkes Land, and enter the ice near Enderby Land. Thenceforth its progress will depend on the character of that region. The general idea is to work slowly southwestward into the Weddell Sea, sending out sledge expeditions to explore any lands that may be seen. The proposed route of the ship has the drawback that it may be contrary to the prevalent drift of the ice and currents. Accordingly the expedition has been equipped on the expectation of a long, slow battle

with the ice. The 'Gauss' has been designed for strength, not speed, and has been fitted up so as to make the minimum possible demands on its coal consumption for steaming, scientific work and domestic use. The number of the staff has been kept lower than on the English expedition so that the food supply may be larger and last longer. To make up for the smallness of the crew, 70 dogs have been provided for sledge expeditions. Further various tempting fields of scientific work are to be left unentered as impracticable with the available cargo capacity of the ship.

The Swedish and Scotch expeditions both go to an area where the opportunity for work largely depends on the particular ice conditions of the season. If the ice be open and the Weddell Sea fairly clear, they may reach high latitudes and discover the southern boundary of the South Atlantic basin. As so much depends on the chances of the weather, the plan in both cases is to establish stations on shore as far south as possible, and for the ships to leave the ice at the end of the summer and undertake oceanographic research outside the ice pack during the winter.

III. *The Problems of the Antarctic.*

The frequency of enquiries as to the practical value of Antarctic research shows that popular interest in the subject still values results from what it chooses to call their 'usefulness.' Information as to the meteorology and magnetic phenomena of the Antarctic regions may prove of value in navigation and weather prediction. Unexpected stores of economic products may be found on land or at sea. Nevertheless it must be admitted that the hope of practical rewards is a less powerful incentive to Antarctic exploration than the desire for new facts of theoretical value. The expeditions seek knowledge because it is knowledge rather than because it may be power. The first problem which the collated reports of the four expeditions will be expected to answer is whether the hypothetical 'Terra Australis' has any existence at the present day. Opinions are divided on this question. According to one school the Antarctic lands mostly belong to a great south polar continent; according to another there is no continent but only a number of comparatively small and widely scattered islands. Sir John Murray is the leading champion of the continental hypothesis; he has sketched the probable outline of his 'Antarctica' and represents it as an irregularly triangular area, of a size fully entitling it to rank as a continent.

That the Antarctic lands belong to a continent *geologically* there can be no doubt; for rocks of a typical continental character have now been collected from most of them, including Victoria Land, Wilkes Land and Graham Land. Specimens are now especially wanted

from Dougherty Island and Peter Island in the southern Pacific. Meteorological evidence supports the idea that the Antarctic is still a continent *geographically,* and that the center of the land is not coincident with the south pole, but is in the eastern part of the area.

The available evidence appears to be decidedly in favor of Sir John Murray's theory, though the question cannot be definitely settled until the range of the land has been mapped. This task may be facilitated by the guidance as to the probable trend and position of the coasts, that is given by the principles of geomorphology.

If the current theory of the structural unity of the Pacific ocean be correct, then that ocean must be bounded on the south by a coast of the 'Pacific type.' With one exception in Central America the whole of the known coasts of the Pacific belong to what Suess has called the 'Pacific type.' The main character of this form of coast is that the trend is determined by mountain ranges running parallel to the shore. In the South Pacific this type is well exemplified by New Zealand on one side and by the Andes of South America on the other. In southern Patagonia the Andes are turned from their meridional course and run eastward across Terra del Fuego. The tectonic line of the Andes is then apparently bent suddenly southward and reappears in Graham Land. It is probably continued round the southern Pacific, meeting the known end of the New Zealand line near Mounts Erebus and Terror.

The theory of the structural unity of the Pacific is sufficiently established to render it probable that Cook was close to land when he turned back from his furthest south in the South Pacific (71°S. 122°E.), that the 'ice-barriers' of Ross and Bellingshausen are both the fronts of glaciers flowing from highlands to the south; that there is a land connection of the Pacific coast type running from Ross's ice barriers northeastward to Graham Land; and that Victoria Land is connected to Wilkes Land by a broad bight.

There are no such data for predictions as to the distribution of land and water in the German and Scotch areas of work. For Wilkes Land and the lands that may extend thence westward towards Graham Land are no doubt plateau countries bounded to the north by coasts of the 'Atlantic type'; and the trend of such coasts is not determined by simple continuous tectonic lines. That Wilkes Land and Geikie Land repeat the structure of southern Australia is rendered probable by the geological collections of all the expeditions from Wilkes to the 'Southern Cross.' The westward extension of this land line has probably the same structure, and it is accordingly impossible to predict how far the Weddell cuts into the Antarctic lands.

The principles of geomorphology not only suggest the external shape of 'Antarctica' but also its internal relief. It is probable that it

is not a dome of land increasing in height slowly from the coasts to a central point near the South Pole; it is more likely to consist of a lofty mountain range running near the Pacific shore and of a broad plateau sloping downward from this mountain axis across the pole to Weddell Sea on the one side and the bight between Wilkes Land and Enderby Land on the other.

The remaining problems of the Antarctic are of less general and more technical interest. The magnetic survey, the need for which led to the British Government's contribution of £45,000 to the cost of the 'Discovery,' is generally regarded as the most important item in the scientific program. The principal point to be determined by the British expedition is the variation in the magnetic elements since the surveys of Ross and of Clerk and Moore. The deep fauna of the Antarctic seas was proved by the 'Challenger' and the 'Belgica' to be rich in new forms of life; and according to Murray the Antarctic and Arctic faunas have many elements in common. More material is needed for the proper analysis of the resemblances between the two faunas, and the collections may be expected to yield some hitherto undiscovered animals of ancient types.

The exact shape of the earth is another question which cannot be settled without fresh evidence from the Antarctic. For this purpose two at least of the expeditions have been provided with pendulum outfits; by noting the exact length of time occupied by the swing of a pendulum the distance of the place of observation from the earth's center can be determined. It is held that the south polar region projects further from the plane of the equator than does the north polar region; according to one estimate the south pole is slightly more than one hundredth further from the earth's center than the north pole.

The work of the expeditions includes researches in the physics of glacier ice, a subject in which Professor von Drygalski is an expert, on the distribution and spectroscopic phenomena of the Aurora; on the composition and movements of the atmosphere, and the currents of the Antarctic Seas.

If the explorers only have the success which they deserve their arduous and devoted labors will contribute materially toward the progress of many branches of science. In fact, as Sir John Murray assures us, 'the results of a successful Antarctic expedition would mark a great advance in the philosophy—apart from the mere facts—of terrestrial science.'

THE POSSIBLE IMPROVEMENT OF THE HUMAN BREED UNDER THE EXISTING CONDITIONS OF LAW AND SENTIMENT.*

By FRANCIS GALTON, D.C.L., D.Sc., F.R.S.,
LONDON.

IN fulfilling the honorable charge that has been entrusted to me of delivering the Huxley lecture, I shall endeavor to carry out what I understand to have been the wish of its founders, namely, to treat broadly some new topic belonging to a class in which Huxley himself would have felt a keen interest, rather than to expatiate on his character and the work of his noble life.

That which I have selected for to-night is one which has occupied my thoughts for many years, and to which a large part of my published inquiries have borne a direct though silent reference. Indeed, the remarks I am about to make would serve as an additional chapter to my books on 'Hereditary Genius' and on 'Natural Inheritance.' My subject will be the possible improvement of the human race under the existing conditions of law and sentiment. It has not hitherto been approached along the ways that recent knowledge has laid open, and it occupies in consequence a less dignified position in scientific estimation than it might. It is smiled at as most desirable in itself and possibly worthy of academic discussion, but absolutely out of the question as a practical problem. My aim in this lecture is to show cause for a different opinion. Indeed I hope to induce anthropologists to regard human improvement as a subject that should be kept openly and squarely in view, not only on account of its transcendent importance, but also because it affords excellent but neglected fields for investigation. I shall show that our knowledge is already sufficient to justify the pursuit of this, perhaps the grandest of all objects, but that we know less of the conditions upon which success depends than we might and ought to ascertain. The limits of our knowledge and of our ignorance will become clearer as we proceed.

Human Variety.

The natural character and faculties of human beings differ at least as widely as those of the domesticated animals, such as dogs and horses, with whom we are familiar. In disposition some are gentle and good-

* The second Huxley Lecture of the Anthropological Institute, delivered on October 29, 1901.

tempered, others surly and vicious; some are courageous, others timid; some are eager, others sluggish; some have large powers of endurance, others are quickly fatigued; some are muscular and powerful, others are weak; some are intelligent, others stupid; some have tenacious memories of places and persons, others frequently stray and are slow at recognizing. The number and variety of aptitudes, especially in dogs, is truly remarkable; among the most notable being the tendency to herd sheep, to point and to retrieve. So it is with the various natural qualities that go towards the making of civic worth in man. Whether it be in character, disposition, energy, intellect or physical power, we each receive at our birth a definite endowment, allegorized by the parable related in St. Matthew, some receiving many talents, others few; but each person being responsible for the profitable use of that which has been entrusted to him.

Distribution of Qualities in a Nation.

Experience shows that while talents are distributed in endless different degrees, the frequency of those different degrees follows certain statistical laws, of which the best known is the Normal Law of Frequency. This is the result whenever variations are due to the combined action of many small and different causes, whatever may be the causes and whatever the object in which the variations occur, just as twice 2 always makes 4, whatever the objects may be. It therefore holds true with approximate precision for variables of totally different sorts, as, for instance, stature of man, errors made by astronomers in judging minute intervals of time, bullet marks around the bull's-eye in target practice, and differences of marks gained by candidates at competitive examinations. There is no mystery about the fundamental principles of this abstract law; it rests on such simple fundamental conceptions as, that if we toss two pence in the air they will, in the long run, come down one head and one tail twice as often as both heads or both tails. I will assume then, that the talents, so to speak, that go to the formation of civic worth are distributed with rough approximation according to this familiar law. In doing so, I in no way disregard the admirable work of Professor Karl Pearson on the distribution of qualities, for which he was adjudged the Darwin Medal of the Royal Society a few years ago. He has amply proved that we must not blindly trust the Normal Law of Frequency; in fact, that when variations are minutely studied they rarely fall into that perfect symmetry about the mean value which is one of its consequences. Nevertheless, my conscience is clear in using this law in the way I am about to. I say that *if* certain qualities vary normally, such and such will be the results; that these qualities are of a class that are found, whenever they have been tested, to vary

normally to a fair degree of approximation, and consequently we may infer that our results are trustworthy indications of real facts.

A talent is a sum whose exact value few of us care to know, although we all appreciate the inner sense of the beautiful parable. I will, therefore, venture to adapt the phraseology of the allegory to my present purpose by substituting for 'talent' the words 'normal-talent.' The value of this normal-talent in respect to each and any specified quality or faculty is such that one-quarter of the people receive for their respective shares more than one normal-talent *over and above* the average of all the shares. Our normal-talent is therefore identical with what is technically known as the 'probable error.' Therefrom the whole of the following table starts into life, evolved from that of the '*probability integral.*' It expresses the distribution of any normal

TABLE I.—*Normal Distribution (to the nearest per ten thousand and to the nearest per hundred).*

	−4°	−3°	−2°	−1°	M +1°	+2°	+3°	+4°		
v and below	*u*	*t*	*s*	*r*	R	S	T	U	V and above.	Total
35	180	672	1613	2500	2500	1613	672	180	35	10,000
2		7	16	25	25	16	7	2		100

quality, or any group of normal qualities, among 10,000 persons in terms of the normal-talent. The M in the upper line occupies the position of Mediocrity, or that of the average of what all have received: the +1°, +2°, etc., and the −1°, −2°, etc., refer to normal talents. These numerals stand as graduations at the heads of the vertical lines by which the table is divided. The entries between the divisons are the numbers per 10,000 of those who receive sums between the amounts specified by those divisions. Thus, by the hypothesis, 2,500 receive more than M but less than M+1°, 1,613 receive more than M+1° but less than M+2°, and so on. The terminals have only an inner limit, thus 35 receive more than 4°, some to perhaps a very large but indefinite amount. The divisions might have been carried much farther, but the numbers in the classes between them would become less and less trustworthy. The left half of the series exactly reflects the right half. As it will be useful henceforth to distinguish these classes, I have used the *capital* or large letters, R, S, T, U, V, for those above mediocrity and corresponding *italic* or small letters, *r, s, t, u, v,* for those below mediocrity, *r* being the counterpart of R, *s* of S, and so on.

In the lowest line the same values are given, but more roughly, to the nearest whole percentage.

It will assist in comprehending the values of different grades of

civic worth to compare them with the corresponding grades of adult male stature in our nation. I will take the figures from my 'Natural Inheritance,' premising that the distribution of stature in various peoples has been well investigated and shown to be closely normal. The average height of the adult males, to whom my figures refer, was nearly 5 feet 8 inches, and the value of their 'normal-talent' (which is a measure of the spread of distribution) was very nearly 1¾ inches. From these data it is easily reckoned that Class U would contain men whose heights exceed 6 feet 1¼ inches. Even they are tall enough to overlook a hatless mob, while the higher classes, such as V, W and X, tower above it in an increasingly marked degree. So the civic worth (however that term may be defined) of U-class men, and still more of V-class, are notably superior to the crowd, though they are far below the heroic order. The rarity of a V-class man in each specified quality or group of qualities is as 35 in 10,000, or say, for the convenience of using round numbers, as 1 to 300. A man of the W class is ten times rarer, and of the X class rarer still; but I shall avoid giving any more exact definition of X than as a value considerably rarer than V. This gives a general but just idea of the distribution throughout a population of each and every quality taken separately so far as it is normally distributed. As already mentioned, it does the same for *any* group of normal qualities; thus, if marks for classics and for mathematics were severally normal in their distribution, the combined marks gained by each candidate in both those subjects would be distributed normally also, this being one of the many interesting properties of the law of frequency.

Comparison of the Normal Classes with those of Mr. Booth.

Let us now compare the normal classes with those into which Mr. Charles Booth has divided the population of all London, in a way that corresponds not unfairly with the ordinary conception of grades of civic worth. He reckons them from the lowest upwards, and gives the numbers in each class for East London. Afterwards he treats all London in a similar manner, except that sometimes he combines two classes into one and gives the joint result. For my present purpose, I had to couple them somewhat differently, first disentangling them as I best could. There seemed no better way of doing this than by assigning to the members of each couplet the same proportions that they had in East London. Though this was certainly not accurate, it is probably not far wrong. Mr. Booth has taken unheard-of pains in this great work of his to arrive at accurate results, but he emphatically says that his classes cannot be separated sharply from one another. On the contrary, their frontiers blend, and this justifies me in taking slight liberties with his figures. His class A consists of criminals, semi-

criminals, loafers and some others, who are in number at the rate of 1 per cent. in all London—that is 100 per 10,000, or nearly three times as many as the *v* class: they therefore include the whole of *v* and spread upwards into the *u*. His class B consists of very poor persons who subsist on casual earnings, many of whom are inevitably poor from shiftlessness, idleness or drink. The numbers in this and the A class combined closely correspond with those in *t* and all below *t*.

Class C are supported by intermittent earnings; they are a hard-working people, but have a very bad character for improvidence and shiftlessness. In Class D the earnings are regular, but at the low rate of twenty-one shillings or less a week, so none of them rise above poverty, though none are very poor. D and C together correspond to the whole of *s* combined with the lower fifth of *r*. The next class, E, is the largest of any, and comprises all those with regular standard earnings of twenty-two to thirty shillings a week. This class is the recognized field for all forms of cooperation and combination; in short for trades unions. It corresponds to the upper four fifths of *r* and the lower four-fifths of R. It is therefore essentially the mediocre class, standing as far below the highest in civiç worth as it stands above the lowest class with its criminals and semi-criminals. Next above this large mass of mediocrity comes the honorable class *F*, which consists of better paid artisans and foremen. These are able to provide adequately for old age, and their sons become clerks and so forth. *G* is the lower middle class of shop-keepers, small employers, clerks and subordinate professional men, who as a rule are hard-working, energetic and sober. F and G combined correspond to the upper fifth of R and the whole of S, and are, therefore, a counterpart to D and C. All above G are put together by Mr. Booth into one class H, which corresponds to our T, U, V and above, and is the counterpart of his two lowermost classes, A and B. So far, then, as these figures go, civic worth is distributed in fair approximation to the normal law of frequency. We also see that the classes *t, u, v* and below are undesirables.

Worth of Children.

The brains of the nation lie in the higher of our classes. If such people as would be classed W or X could be distinguishable as children and procurable by money in order to be reared as Englishmen, it would be a cheap bargain for the nation to buy them at the rate of many hundred or some thousands of pounds per head. Dr. Farr, the eminent statistician, endeavored to estimate the money worth of an average baby born to the wife of an Essex laborer and thenceforward living during the usual time and in the ordinary way of his class. Dr. Farr, with accomplished actuarial skill, capitalized the value at the child's birth of two classes of events, the one the cost of maintenance while a

child and when helpless through old age, the other its earnings as boy and man. On balancing the two sides of the account the value of the baby was found to be five pounds. On a similar principle, the worth of an X-class baby would be reckoned in thousands of pounds. Some such 'talented' folk fail, but most succeed, and many succeed greatly. They found great industries, establish vast undertakings, increase the wealth of multitudes and amass large fortunes for themselves. Others, whether they be rich or poor, are the guides and light of the nation, raising its tone, enlightening its difficulties and imposing its ideals. The great gain that England received through the immigration of the Huguenots would be insignificant to what she would derive from an annual addition of a few hundred children of the classes W and X. I have tried, but not yet succeeded to my satisfaction, to make an approximate estimate of the worth of a child at birth according to the class he is destined to occupy when adult. It is an eminently important subject for future investigators, for the amount of care and cost that might profitably be expended in improving the race clearly depends on its result.

Descent of Qualities in a Population.

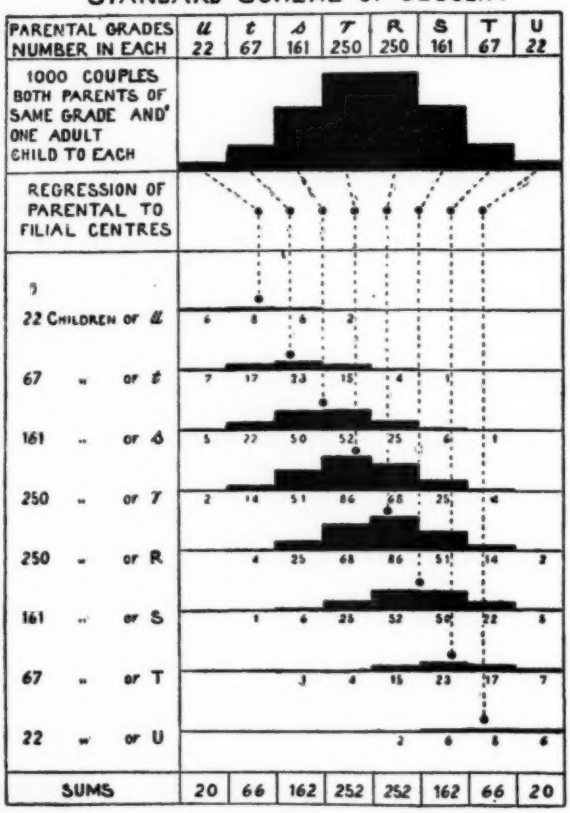
Let us now endeavor to obtain a correct understanding of the way in which the varying qualities of each generation are derived from those of its predecessor. How many, for example, of the V class in the offspring come respectively from the V, U, T, S and other classes of parentage? The means of calculating this question for a normal population are given fully in my 'Natural Inheritance.' There are three main senses in which the word parentage might be used. They differ widely, so the calculations must be modified accordingly. (1) The amount of the quality or faculty in question may be known in each parent. (2) It may be known in only one parent. (3) The two parents may belong to the same class, a V-class father in the scale of male classification always marrying a V-class mother, occupying identically the same position in the scale of female classification.

I select this last case to work out as being the one with which we shall here be chiefly concerned. It has the further merit of escaping some tedious preliminary details about converting female faculties into their corresponding male equivalents, before men and women can be treated statistically on equal terms. I shall assume in what follows that we are dealing with an ideal population, in which all marriages are equally fertile, and which is statistically the same in successive generations both in numbers and in qualities, so many per cent. being always this, so many always that, and so on. Further, I shall take no notice of offspring who die before they reach the age of marriage, nor shall I regard the slight numerical inequality of the sexes, but will

simply suppose that each parentage produces one couplet of grown-up filials, an adult man and an adult woman.

The result is shown to the nearest whole per thousand in the diagram up to 'U and above.' It may be read either as applying to fathers and their sons when adult, or to mothers and their daughters when adult, or, again, to parentages and filial couplets. I will not now attempt to explain the details of the calculation to those to whom these methods

STANDARD SCHEME OF DESCENT



are new. Those who are familiar with them will easily understand the exact process from what follows. There are three points of reference in a scheme of descent which may be respectively named 'mid-parental,' 'genetic' and 'filial' centers. In the present case of both parents being alike, the position of the mid-parental center is identical with that of either parent separately. The position of the filial center is that from which the children disperse. The genetic center occupies the same position in the parental series that the filial center does in the filial series. 'Natural Inheritance' contains abundant proof, both observational and

theoretical, that the genetic center is not and cannot be identical with the parental center, but is always more mediocre, owing to the combination of ancestral influences—which are generally mediocre—with the purely parental ones. It also shows that the regression from the parental to the genetic center, in the case of stature at least, would amount to two thirds under the conditions we are now supposing. The regression is indicated in the diagram by converging lines which are directed towards the same point below, but are stopped at one third of the distance on the way to it. The contents of each parental class are supposed to be concentrated at the foot of the median axis of that class, this being the vertical line that divides its contents into equal parts. Its position is approximately, but not exactly, half-way between the divisions that bound it, and is as easily calculated for the extreme classes, which have no outer terminals, as for any of the others. These median points are respectively taken to be the positions of the parental centers of the whole of each of the classes; therefore the positions attained by the converging lines that proceed from them at the points where they are stopped, represent the genetic centers. From these the filials disperse to the right and left with a 'spread' that can be shown to be three quarters that of the parentages. Calculation easily determines the number of the filials that fall into the class in which the filial center is situated, and of those that spread into the classes on each side. When the parental contributions from all the classes to each filial class are added together they will express the distribution of the quality among the whole of the offspring. Now it will be observed in the table that the numbers in the classes of the offspring are identical with those of the parents, when they are reckoned to the nearest whole percentage, as should be the case according to the hypothesis. Had the classes been narrower and more numerous, and if the calculations had been carried on to two more places of decimals, the correspondence would have been identical to the nearest ten-thousandth. It was unnecessary to take the trouble of doing this, as the table affords a sufficient basis for what I am about to say. Though it does not profess to be more than approximately true in detail, it is certainly trustworthy in its general form, including as it does the effects of regression, filial dispersion, and the equation that connects a parental generation with a filial one when they are statistically alike. Minor corrections will be hereafter required, and can be applied when we have a better knowledge of the material. In the meantime it will serve as a standard table of descent from each generation of a people to its successor.

Economy of Effort.

I shall now use the table to show the economy of concentrating our attention upon the highest classes. We will therefore trace the origin

of the V class—which is the highest in the table. Of its 34 or 35 sons, 6 come from V parentages, 10 from U, 10 from T, 5 from S, 3 from R, and none from any class below R. But the numbers of the contributing parentages have also to be taken into account. When this is done, we see that the lower classes make their scores owing to their quantity and not to their quality; for while 35 V-class parents suffice to produce 6 sons of the V class, it takes 2,500 R-class fathers to produce 3 of them. Consequently the richness in produce of V-class parentages is to that of the R-class in an inverse ratio, or as 143 to 1. Similarly, the richness in produce of V-class children from parentages of the classes U, T, S, respectively, is as 3, 11½ and 55, to 1. Moreover, nearly one-half of the produce of V-class parentages are V or U taken together, and nearly three quarters of them are either V, U or T. If then we desire to increase the output of V-class offspring, by far the most profitable parents to work upon would be those of the V class, and in a threefold less degree those of the U class.

When both parents are of the V class the quality of parentages is greatly superior to those in which only one parent is a V. In that case the regression of the genetic center goes twice as far back towards mediocrity, and the spread of the distribution among filials becomes nine tenths of that among the parents, instead of being only three-quarters. The effect is shown in Table II.

TABLE II.—*Distribution of Sons.* (1) *One parent of class V., the other unknown.* (2) *Both parents of class* V (*from Table II., with decimal point and an* o).

	Distribution of Sons								Total
	t	*s*	*r*	R	S	T	U	V	
One V-parent	0.3	1.2	3.5	7.9	9.6	7.5	3.6	1.3	34.3
Two V-parents				3.0	5.0	10.0	10.0	6 0	34.0

Position of the filial center of (1) = 1.44, of (2) = 2.89. When both parents are T it = 1.58.

There is a difference of fully two divisions in the position of the genetic center, that of the single V parentage being only a trifle nearer mediocrity than that of the double T. Hence it would be bad economy to spend much effort in furthering marriages with a high class on only one side.

Marriage of Like to Like.

In each class of society there is a strong tendency to intermarriage, which produces a marked effect in the richness of brain power of the more cultured families. It produces a still more marked effect of another kind at the lowest step of the social scale, as will be painfully evident from the following extracts from the work of Mr. C. Booth

(i. 38), which refer to his Class A, who form, as has been said, the lowermost third of our '*v* and below.' "Their life is the life of savages, with vicissitudes of extreme hardship and occasional excess. From them come the battered figures who slouch through the streets and play the beggar or the bully. They render no useful service, they create no wealth, more often they destroy it. They degrade whatever they touch, and as individuals are perhaps incapable of improvement . . . but I do not mean to say that there are not individuals of every sort to be found in the mass. Those who are able to wash the mud may find some gems in it. There are at any rate many very piteous cases. Whatever doubt there may be as to the exact numbers of this class, it is certain that they bear a very small proportion to the rest of the population, or even to Class B, with which they are mixed up and from which it is at times difficult to separate them. . . . They are barbarians, but they are a handful. . . ." He says further, "It is much to be desired and to be hoped that this class may become less hereditary in its character; there appears to be no doubt that it is now hereditary to a very considerable extent."

Many who are familiar with the habits of these people do not hesitate to say that it would be an economy and a great benefit to the country if all habitual criminals were resolutely segregated under merciful surveillance and peremptorily denied opportunities for producing offspring. It would abolish a source of suffering and misery to a future generation, and would cause no unwarrantable hardship in this.

Diplomas.

It will be remembered that Mr. Booth's classification did not help us beyond classes higher than S in civic worth. If a strong and widely felt desire should arise, to discover young men whose position was of the V, W or X order, there would not be much difficulty in doing so. Let us imagine, for a moment, what might be done in any great university, where the students are in continual competition in studies, in athletics, or in public meetings, and where their characters are publicly known to associates and to tutors. Before attempting to make a selection, acceptable definitions of civic worth would have to be made in alternative terms, for there are many forms of civic worth. The number of men of the V, W or X classes whom the university was qualified to contribute annually must also be ascertained. As was said, the proportion in the general population of the V class to the remainder is as 1 to 300, and that of the W class as 1 in 3,000. But students are a somewhat selected body because the cleverest youths, in a scholastic sense, usually find their way to universities. A considerably high level, both intellectually and physically, would be required as a qualification for candidature. The limited number who had not been auto-

matically weeded away by this condition might be submitted in some appropriate way to the independent votes of fellow-students on the one hand, and of tutors on the other, whose ideals of character and merit necessarily differ. This ordeal would reduce the possible winners to a very small number, out of which an independent committee might be trusted to make the ultimate selection. They would be guided by personal interviews. They would take into consideration all favorable points in the family histories of the candidates, giving appropriate hereditary weight to each. Probably they would agree to pass over unfavorable points, unless they were notorious and flagrant, owing to the great difficulty of ascertaining the real truth about them. Ample experience in making selections has been acquired even by scientific societies, most of which work well, including perhaps the award of their medals, which the fortunate recipients at least are tempted to consider judicious. The opportunities for selecting women in this way are unfortunately fewer, owing to the smaller number of female students between whom comparisons might be made on equal terms. In the selection of women, when nothing is known of their athletic proficiency, it would be especially necessary to pass a high and careful medical examination; and as their personal qualities do not usually admit of being tested so thoroughly as those of men, it would be necessary to lay all the more stress on hereditary family qualities, including those of fertility and prepotency.

Correlation between Promise in Youth and subsequent Performance.

No serious difficulty seems to stand in the way of classifying and giving satisfactory diplomas to youths of either sex, supposing there were a strong demand for it. But some real difficulty does lie in the question—Would such a classification be a trustworthy forecast of qualities in later life? The scheme of descent of qualities may hold good between the parents and the offspring at similar ages, but that is not the information we really want. It is the descent of qualities from men to men, not from youths to youths. The accidents that make or mar a career do not enter into the scope of this difficulty. It resides entirely in the fact that the development does not cease at the time of youth, especially in the higher natures, but that faculties and capabilities which were then latent subsequently unfold and become prominent. Putting aside the effects of serious illness, I do not suppose there is any risk of retrogression in capacity before old age comes on. The mental powers that a youth possesses continue with him as a man; but other faculties and new dispositions may arise and alter the balance of his character. He may cease to be efficient in the way of which he gave promise, and he may perhaps become efficient in unexpected directions.

The correlation between youthful promise and performance in mature life has never been properly investigated. Its measurement presents no greater difficulty, so far as I can foresee, than in other problems which have been successfully attacked. It is one of those alluded to in the beginning of this lecture as bearing on race-improvement, and being on its own merits suitable for anthropological inquiry. Let me add that I think its neglect by the vast army of highly educated persons who are connected with the present huge system of competitive examinations to be gross and unpardonable. Neither schoolmasters, tutors, officials of the universities, nor of the State department of education, have ever to my knowledge taken any serious step to solve this important problem, though the value of the present elaborate system of examinations cannot be rightly estimated until it is solved. When the value of the correlation between youthful promise and adult performance shall have been determined, the figures given in the table of descent will have to be reconsidered.

Augmentation of Favored Stock.

The possibility of improving the race of a nation depends on the power of increasing the productivity of the best stock. This is far more important than that of repressing the productivity of the worst. They both raise the average, the latter by reducing the undesirables, the former by increasing those who will become the lights of the nation. It is therefore all important to prove that favor to selected individuals might so increase their productivity as to warrant the expenditure in money and care that would be necessitated. An enthusiasm to improve the race would probably express itself by granting diplomas to a select class of young men and women, by encouraging their intermarriages, by hastening the time of marriage of women of that high class, and by provision for rearing children healthily. The means that might be employed to compass these ends are dowries, especially for those to whom moderate sums are important, assured help in emergencies during the early years of married life, healthy homes, the pressure of public opinion, honors, and above all the introduction of motives of religious or quasi-religious character. Indeed, an enthusiasm to improve the race is so noble in its aim that it might well give rise to the sense of a religious obligation. In other lands there are abundant instances in which religious motives make early marriages a matter of custom, and continued celibacy to be regarded as a disgrace, if not a crime. The customs of the Hindoos, also of the Jews, especially in ancient times, bear this out. In all costly civilizations there is a tendency to shrink from marriage on prudential grounds. It would, however, be possible so to alter the conditions of life that the most prudent course for an X class person should lie exactly opposite to its present direction, for

he or she might find that there were advantages and not disadvantages in early marriage, and that the most prudent course was to follow their natural instincts.

We have now to consider the probable gain in the number and worth of adult offspring to these favored couples. First as regards the effect of reducing the age at marriage. There is unquestionably a tendency among cultured women to delay or even to abstain from marriage; they dislike the sacrifice of freedom and leisure, of opportunities for study and of cultured companionship. This has to be reckoned with. I heard of the reply of a lady official of a College for Women to a visitor who inquired as to the after life of the students. She answered that one third profited by it, another third gained little good, and a third were failures. 'But what becomes of the failures?' 'Oh, they marry.'

There appears to be a considerable difference between the earliest age at which it is physiologically desirable that a woman should marry and that at which the ablest, or at least the most cultured, women usually do. Acceleration in the time of marriage, often amounting to 7 years, as from 28 or 29 to 21 or 22, under influences such as those mentioned above, is by no means improbable. What would be its effect on productivity? It might be expected to act in two ways:

(1) By shortening each generation by an amount roughly proportionate to the diminution in age at which marriage occurs. Suppose the span of each generation to be shortened by one sixth, so that six take the place of five, and that the productivity of each marriage is unaltered, it follows that one sixth more children will be brought into the world during the same time, which is, roughly, equivalent to increasing the productivity of an unshortened generation by that amount.

(2) By saving from certain barrenness the earlier part of the child-bearing period of the woman. Authorities differ so much as to the direct gain of fertility due to early marriage that it is dangerous to express an opinion. The large and thriving families that I have known were the offspring of mothers who married very young.

The next influence to be considered is that of healthy homes. These and a simple life certainly conduce to fertility. They also act indirectly by preserving lives that would otherwise fail to reach adult age. It is not necessarily the weakest who perish in this way, for instance, zymotic disease falls indiscriminately on the weak and the strong.

Again, the children would be healthier and therefore more likely in their turn to become parents of a healthy stock. The great danger to high civilizations, and remarkably so to our own, is the exhaustive drain upon the rural districts to supply large towns. Those who come up to the towns may produce large families, but there is much reason to

believe that these dwindle away in subsequent generations. In short, the towns sterilize rural vigor.

As one of the reasons for choosing the selected class would be that of hereditary fertility, it follows that the selected class would respond more than other classes to the above influences.

I do not attempt to appraise the strength of the combined six influences just described. If each added one sixth to the produce the number of offspring would be doubled. This does not seem impossible considering the large families of colonists, and of those in many rural districts; but it is a high estimate. Perhaps the fairest approximation may be that these influences would cause the X women to bring into the world an average of one adult son and one adult daughter *in addition* to what they would otherwise have produced. The table of descent applies to one son or to one daughter per couple; it may now be read as specifying the net gain and showing its distribution. Should this estimate be thought too high, the results may be diminished accordingly.

It is no absurd idea that outside influences should hasten the age of marrying and make it customary for the best to marry the best. A superficial objection is sure to be urged that the fancies of young people are so incalculable and so irresistible that they cannot be guided. No doubt they are so in some exceptional cases. I lately heard from a lady who belonged to a county family of position that a great aunt of hers had scandalized her own domestic circle two generations ago by falling in love with the undertaker at her father's funeral and insisting on marrying him. Strange vagaries occur, but considerations of social position and of fortune, with frequent opportunities of intercourse, tell much more in the long run than sudden fancies that want roots. In a community deeply impressed with the desire of encouraging marriages between persons of equally high ability, the social pressure directed to produce the desired end would be so great as to ensure a notable amount of success.

Profit and Loss.

The problem to be solved now assumes a clear shape. A child of the X class (whatever X signifies) would have been worth so and so at its birth, and one of each of the other grades respectively would have been worth so and so; 100 X parentages can be made to produce a net gain of 100 adult sons and 100 adult daughters who will be distributed among the classes according to the standard table of descent. The total value of the prospective produce of the 100 parentages can then be estimated by an actuary, and consequently the sum that it is legitimate to spend in favoring an X parentage. The clear and distinct statement of a problem is often more than half way towards its solution. There seems no reason why this one should not be solved between limiting values that are not too wide apart to be useful.

Existing Activities.

Leaving aside profitable expenditure from a purely money point of view, the existence should be borne in mind of immense voluntary activities that have nobler aims. The annual voluntary contributions in the British Isles to public charities alone amount, on the lowest computation, to fourteen million pounds, a sum which Sir H. Burdett asserts on good grounds is by no means the maximum obtainable. ('Hospitals and Charities,' 1898, p. 85.)

There are other activities long since existing which might well be extended. I will not dwell, as I am tempted to do, on the endowments of scholarships and the like, which aim at finding and educating the fittest youths for the work of the nation; but I will refer to that wholesome practice during all ages of wealthy persons interesting themselves in and befriending poor but promising lads. The number of men who have owed their start in a successful life to help of this kind must have struck every reader of biographies. This relationship of befriender and befriended is hardly to be expressed in English by a simple word that does not connote more than is intended. The word 'patron' is odious. Recollecting Dr. Johnson's abhorrence of the patrons of his day, I turned to an early edition of his dictionary in hope of deriving some amusement as well as instruction from his definition of the word, and I was not disappointed. He defines 'patron' as 'a wretch who supports with insolence and is repaid with flattery.' That is totally opposed to what I would advocate, namely a kindly and honorable relation between a wealthy man who has made his position in the world and a youth who is avowedly his equal in natural gifts, but who has yet to make it. It is one in which each party may well take pride, and I feel sure that if its value were more widely understood it would become commoner than it is.

Many degrees may be imagined that lie between mere befriendment and actual adoption, and which would be more or less effective in freeing capable youths from the hindrances of narrow circumstances; in enabling girls to marry early and suitably, and in securing favor to their subsequent offspring. Something in this direction is commonly but half unconsciously done by many great landowners whose employments for man and wife, together with good cottages, are given to exceptionally deserving couples. The advantage of being connected with a great and liberally managed estate being widely appreciated, there are usually more applicants than vacancies, so selection can be exercised. The consequence is that the class of men found upon these properties is markedly superior to those in similar positions elsewhere. It might well become point of honor, and as much an avowed object, for noble families to gather fine specimens of humanity around them, as it is to procure and maintain fine breeds of cattle and so forth, which are costly, but repay in satisfaction.

There is yet another existing form of princely benevolence which might be so extended as to exercise a large effect on race improvement. I mean the provision to exceptionally promising young couples of healthy and convenient houses at low rentals. A continually renewed settlement of this kind can be easily imagined, free from the taint of patronage, and analogous to colleges with their self-elected fellowships and rooms for residence, that should become an exceedingly desirable residence for a specified time. It would be so in the same way that a good club by its own social advantages attracts desirable candidates. The tone of the place would be higher than elsewhere, on account of the high quality of the inmates, and it would be distinguished by an air of energy, intelligence, health and self-respect and by mutual helpfulness.

Prospects.

It is pleasant to contrive Utopias, and I have indulged in many, of which a great society is one, publishing intelligence and memoirs, holding yearly elections, administering large funds, establishing personal relations like a missionary society with its missionaries, keeping elaborate registers and discussing them statistically with honest precision. But the first and pressing point is to thoroughly justify any crusade at all in favor of race improvement. More is wanted in the way of unbiased scientific inquiry along the many roads I have hurried over, to make every stepping-stone safe and secure, and to make it certain that the game is really worth the candle. All I dare hope to effect by this lecture is to prove that in seeking for the improvement of the race we aim at what is apparently possible to accomplish, and that we are justified in following every path in a resolute and hopeful spirit that seems to lead towards that end. The magnitude of the inquiry is enormous, but its object is one of the highest man can accomplish. The faculties of future generations will necessarily be distributed according to laws of heredity, whose statistical effects are no longer vague, for they are measured and expressed in formulæ. We cannot doubt the existence of a great power ready to hand and capable of being directed with vast benefit as soon as we shall have learnt to understand and to apply it. To no nation is a high human breed more necessary than to our own, for we plant our stock all over the world and lay the foundation of the dispositions and capacities of future millions of the human race.

THE END OF THE FILTH THEORY OF DISEASE.

By Dr. CHARLES V. CHAPIN.

FOR half a century in this country, and for a longer time in England, the filth theory of disease has dominated medical thought and has been accepted with trusting faith by the public, particularly by the better educated portion thereof. The idea that filth is the cause of disease dates back to a much earlier period. It has probably been a common belief among most civilized peoples. In colonial times many of our physicians believed in the close connection between filth and disease, and these notions sometimes found expression in laws. The prevalence of yellow fever in most of our seaboard cities during the last years of the eighteenth century did much to advance the filth theory, for this fever was held by many physicians to be *par excellence* a filth disease. The popular ideas were doubtless illustrated by the legislation enacted in Massachusetts, which provided for the summary removal of 'any nuisance, source of filth or cause of sickness.' This law has since been copied by fourteen states. The filth theory, however, did not become the vogue until the latter half of the nineteenth century. Its great popularity was largely due to the efforts of three men: Chadwick in England, Pettenkoffer in Germany and Shattuck in the United States, but doubtless most of all to Chadwick. Edwin Chadwick was a lawyer and social reformer. He was intensely humanitarian, and the misery then existent in England appealed most strongly to him. He saw that the poor people were filthy and sick, and he assumed that the sickness was due to the filth. There were some who objected that the relationship was not proved, but their objections amounted to little at a time when scientific reasoning was just beginning to find a place in medical thought. The practical reforms brought about by Chadwick and his followers in improved housing for the poor, improved refuse disposal, the introduction of drainage systems and the betterment of water supplies, certainly resulted in increased comfort, and constituted a decided advance in what we call 'civilization.' But they did not exterminate the infectious diseases as had been hoped and promised. The filth theory found strong supporters among engineers, and later among drain-layers and plumbers. These men accepted honestly enough the teaching of their medical advisers, and naturally became active propagandists of a theory which demanded such services as they alone could render.

From the middle until nearly the close of the nineteenth century, the germ theory, during the period when it was little else than a theory, furnished many arguments for those who contended that filth was a fertile source of disease. Putrefaction and fermentation were known to be similar processes, and were believed to be due to the vital activity of minute organisms. There were good grounds for believing that diseases of an infectious nature were also dependent on the growth in the body of similar 'germs,' and this theory from 1850 grew rapidly into favor. The germ theory led Dr. Farr, Registrar General of England, to classify most of the infectious diseases as 'zymotic' or fermentative diseases, for the disease poison was supposed to act, as in truth it does, as a ferment in the blood or other tissues in the body. If both putrefaction and disease were due to the action of minute organisms, what more reasonable than to believe, said the theorists, that putrefying material harbored and developed the 'germs' of disease?

The filth theory then, which has had such a powerful influence on the public mind, assumed that most of the infectious diseases were directly and specifically caused by germs or other more subtle emanations from decaying animal or vegetable matter.

Furthermore, it was claimed that while such emanations might not in every case produce a specific disease, they did tend almost always to affect injuriously the general health, and lower the vitality of persons habitually exposed. Hence the sewer gas theory which has found such acceptance, and which has taught that the gas formed from the filth in drains is so injurious to human life that portions so minute as not to be appreciated by the senses are yet harmful in the extreme. It was taught by medical men and health officials that filth and decay in every form were a serious menace to health, both from the disease germs which they contain, and the poisonous gases which they give off; and this teaching is received and accepted, even to-day, by a large portion of the medical profession, health officers and the public at large.

It is true that ever since this theory was promulgated some have been led to doubt its dicta, because in the first place they often found filth to abound where little zymotic disease existed, and even where the 'general health' of the people was high. On the other hand, zymotic diseases were frequently found in the cleanest of dwellings, and where the best of plumbing kept out all sewer gas. But most sanitary officials accepted the theory as fact, and acted accordingly, some used it simply as a working theory awaiting more definite knowledge, and a few were led by their experience to allow it little weight in their work.

As soon as the germ theory of disease ceased to be a mere theory, and the true facts in regard to the etiology of the infectious diseases began to be known, and bacteriology gave us exact knowledge of the

life history of the minute organisms which are their cause, the erroneous generalizations of the filth theory became apparent. We can now to a large extent discriminate between filth that is dangerous and that which is not. We know that the gaseous emanations from decaying matter do not produce specific disease. We know that the germs themselves are much more rarely air borne than had been thought, and that they are not thrown off into the air from the moist surfaces of the materials where they are largely found.

Observations of cholera outbreaks, both in England and this country, furnished the best arguments for the filth theory. This disease was in a great number of instances traced to wells or streams polluted with leakage from privies or drains. The disease abounded in filthy locations and among filthy people. It was perhaps natural, though not logical, to accuse all filth as likely to produce cholera. We now know that cholera is due to the comma spirillum and that this germ is thrown off from the patient in the discharges from the bowels, but that outside the body it rarely survives a few days, and practically never increases in number. Excrement from cholera patients may infect drinking water and so cause the disease, or among the uncleanly, fecal matter may be pretty directly transferred from one to another, or food may become infected by hands soiled by fecal matter, or the germs may be carried to the food by flies or other insects.

It is not filth that causes cholera, but a particular kind of filth, namely the excrement of cholera patients. Furthermore this filth and its germs are not air borne, they are not breathed in, but taken in through the mouth. This exact knowledge does away with the vague fear of all filth as a cause of the disease, and greatly simplifies the means necessary to control it. It is true that the filth theorists did much to prevent cholera, for in their warfare against filth they demanded a water supply from a source which could not be contaminated, and they demanded sewers to remove all excremental matter. These great public improvements make it far easier to control cholera than it was before their inception. The filth theorists were successful thus far, because, so far as cholera was concerned, there was a modicum of truth in their theory.

What has been said of cholera is applicable also to typhoid fever. This disease is due to a bacillus which does not grow outside of the body, but is carried in excremental filth just as is the cholera spirillum, and it must be controlled in just the same way.

The diphtheria bacillus is also strictly parasitic and grows, except in rare instances, on the mucous membrane of human beings. From persons so infected it is transmitted to others, usually by means of cups, spoons, pencils or other articles, or directly by kissing or fondling. Diphtheria was a few years ago considered a filth disease and was

often attributed to sewer gas. We now know that the only filth to be feared is the secretions of infected persons.

Bubonic plague has always been classed as a typical filth disease, but here again careful laboratory work has resulted in a vastly clearer knowledge of its causation, though a great deal yet remains to be learned. The bacillus which causes it was discovered by Kitasato in 1894; and it has been found that it rarely if ever increases in numbers outside of the body, but rather tends to die off, frequently very rapidly. There is much reason to think that fleas and rats become infected, and are important factors in the spread of the disease, though more evidence on this point is to be desired. In any event it is shown to be a contagious disease, though perhaps not usually directly contagious, and that it does not develop in filth. We might have a perfectly drained city, with modern plumbing, efficient scavenging and the purest of water, yet, if the inhabitants were careless in their habits and opposed isolation, the disease would spread as in an undrained and poorly watered city. It might require rats and fleas to cause an epidemic; but these animals played no part in the filth theory.

Tuberculosis was never classed as a filth disease, though the introduction of sewers has been held to cause its decrease, it is claimed by draining the soil. It has, however, been proved to be a bacterial disease, but the bacillus will not grow outside of the body and has no relation to filth, except so far as matter expectorated by a consumptive is filth.

Typhus fever, smallpox, scarlet fever, measles and whooping cough have by some enthusiasts been attributed to filth, but very few observant persons who have studied the distribution of these diseases and followed their outbreaks consider them other than purely contagious. They, of course, never originate in filth or develop in filth, but may spread more among filthy people just because such persons use very little soap and water and allow their faces, hands, belongings and dwellings to become and remain smeared with mucus, saliva, pus and other infectious material.

Malaria has for centuries been considered to be the product of decaying vegetable matter, but its true relation to such material has only recently been discovered. The mosquito is the bearer of the malarial parasite, which in this case is a protozoan rather than a bacterium, and the larvæ of the particular species of mosquitoes which carry this disease live only in shallow pools where they are protected from their enemies and find an abundance of food. Water which is really filthy is not congenial to them.

Yellow fever is the one disease which it has been believed could surely be traced to filth. No disease in this country is so dreaded, and its supposed dependence upon filth has made it the last stronghold of the advocates of this theory. It has been held by almost all observers

that this disease is carried in fomites, *i. e.*, lives outside of the body, and is thus implanted in new localities, where it develops in a filthy soil, giving rise to new foci of the disease. We have been taught that by keeping a city thoroughly clean, yellow fever could be excluded as it would find no place to grow. Such methods, however, never have been and never could be successful. We all owe a great debt of gratitude to Surgeon Reed and his associates for teaching us the true method of combating this disease and dealing a death blow to the filth theory. By their experiments in which they failed to transmit the disease by fomites, they showed that the poison, the exact nature of which still remains unknown, does not live outside of the body and therefore can not develop in filth. The mosquitoes which transmit this disease do, unlike the malarial mosquitoes, often breed in filthy water, such as cesspools, dirty gutters and the like, and this doubtless is the kernel of truth in the filth theory of its origin.

Thus one by one the zymotic diseases have been shown to be purely contagious, and not to have their origin in filth. In not a single one of these diseases has our more exact knowledge placed its source outside of man or other animals. But it may be argued that though the specific diseases may not arise from filth, we still have to fear the gaseous products of decomposition, and that the foul emanations from sewers, vaults and dung-heaps may undermine the health and pave the way for these diseases. Probably more sins have been attributed to sewer gas than anything else of this kind, but we now know that the air of modern sewers and well constructed drains is practically harmless. It is true that in confined cesspools and choked drains, injurious gases like sulphuretted hydrogen, marsh gas or carbon dioxide may be formed in such quantities as to be fatal to life, but in ordinary sewers and drains, with their facilities for ventilation and rapid motion of contents, such accumulations are impossible, and a slight leakage of sewer air, which was formerly considered so dangerous, has been shown by the chemists and bacteriologists to be harmless. Foul odors from manure piles, garbage barrels, soap works or offensive manufactories are when concentrated intensely annoying and often nauseating to those who only occasionally breathe them, but those who are constantly exposed to them do not suffer at all and do not notice them. It is also observed that plumbers and sewer cleaners are not at all affected by the odors to which they are exposed. When these odors are slight there is no reason to think that they affect the health at all, and in any event the disturbance which they cause is not lasting. The burden of proof lies with those who claim that the gases of decomposition are a serious menace to health. Most of the alleged proof relates to the production of specific diseases like typhus, typhoid and cholera which we now know can not be caused in any such way. Evidence tried by modern

methods of scientific enquiry is lacking. Such evidence as we have shows that those persons who are constantly exposed to the gaseous products of decomposition do not suffer therefrom.

From whatever point of view this matter is discussed, it must not be forgotten that the advocates of the filth theory did much good, for there was a certain amount of truth in the theory. Certain kinds of filth are conveyors of specific disease, and the efforts to secure better water, to build good sewers and drains, and promptly remove excreta from dwellings were true sanitation. The providing of better houses doubtless conduces to greater personal cleanliness and tends to higher standards of living. Full credit should be given to early reformers who labored earnestly according to their knowledge, and accomplished much good and very little evil. It is only those who in the light of more accurate knowledge still hold to the crude ideas of an earlier age with whom the writer would differ.

In abandoning the filth theory we should profit by experience and not become wedded too closely to the germ theory. We do know much about bacteria and protozoa and their relation to disease, but vastly more remains to be learned, and it is much to be feared that too many seek to enter the sphere of the unknown by hasty speculation rather than by the slow path of laborious research.

Though abandoning the time honored theory which was taught him, the writer has not abandoned the fight against filth. Filth is a nuisance, and is usually an evidence of some one's carelessness of his neighbor's comfort. The state or city should certainly protect its citizens against such nuisances. Good sewerage, well swept streets, prompt scavenging, public baths, clean tenements, are all parts, desirable and essential parts, of our civilization. They would be worth what they cost even if they had no relation to health; but the proper disposal of excreta and cleanliness of person doubtless do have much to do with the prevention of the spread of many communicable diseases. Much is to be gained by promoting cleanliness, but nothing by fostering false notions of the dangers of filth.

RECENT TOTAL ECLIPSES OF THE SUN.

By Professor SOLON I. BAILEY,
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NATURE, when in her sublimest moods, is seldom seen without fear and danger. The tornado furnishes an exhibition full of weird beauty and scientific interest; yet man, in his haste to reach a place of safety, has little time for their contemplation. In the total eclipse of the sun, however, nature provides one spectacle, unsurpassed in grandeur, which may be observed in perfect safety. There was a time, indeed, when the chief emotion caused by an eclipse was fear, that superstitious dread of impending evil, which the presence of the unknown causes. This has now passed away, with the increase of knowledge. Perhaps no better illustration of the changed thought of the world in regard to natural phenomena could be found than a comparison of the following extracts. The first is from the early English chroniclers; William of Malmesbury, writing of the eclipse of March 20, 1140, says:

> At the ninth hour of the fourth day of the week, there was an eclipse throughout England as I have heard. With us, indeed, and with all our neighbors, the obscuration of the sun also was so remarkable that persons sitting at table, for it was Lent, at first feared that chaos was come again; afterwards, learning the cause, they went out and beheld the stars around the sun. It was thought and said by many not untruly that the king would not continue a year in the government.

The 'New York Herald' of January 2, 1889, announced the eclipse of the previous day with the following headlines: "The Sun Knocked Out. After about two minutes it comes up smiling. Viewing the Eclipse. Clear skies almost universal along the belt of totality. Fine photographs taken," etc., etc.

Scientific study is now the chief attraction of an eclipse, although its spectacular beauty is appreciated as never before. Many natural phenomena, which otherwise would attract the systematic attention of scientists, fail to do this in consequence of the irregularity with which they occur. An eclipse of the sun, however, can be computed many years in advance, so that careful plans can be made for its observance. Even here grave trouble is caused by the uncertainties of meteorological science. It is a striking and somewhat discouraging fact that, while one can compute with reasonable accuracy the place and time of an eclipse a hundred years in advance, he cannot safely predict a single

day before the event whether the sky will be clear or clouded. Under these circumstances it is not surprising that many people do not travel to the scenes of total eclipses. Expeditions to eclipses were practically unknown until half a century ago. Before that time man received with varied emotions those which Providence sent him, but did not travel far to seek them. Now, expeditions half way round the earth are common. This is not due entirely to the greater scientific zeal of the present day; probably few living astronomers would care to journey to the antipodes for an eclipse, under the conditions of travel which prevailed one or two centuries ago.

About seventy total eclipses of the sun occur each century. The average duration is, perhaps, three minutes, which amounts to about three and a half hours per century. If some Wandering Jew, at the beginning of the Christian era, had started to observe total eclipses of the sun, and had visited every one possible since that time, he would have had less than three whole days for observation. The time, indeed, would have been much less, since many of these eclipses occurred on the ocean, or at inaccessible regions of the earth, and clouds undoubtedly obscured the sky during half the time of totality. During the last half century, since spectroscopic observations have been carried on, the time during which an individual could have obtained favorable observations has been little, if any, more than a single hour. Under these circumstances the wonder is that it has been possible to accomplish so much. Many men, however, have worked at different stations along the narrow but extended path of totality, and every device which ingenuity could suggest has been utilized in order to obtain as much as possible in the brief seconds of totality. Nothing has contributed so much to increase the amount and accuracy of the results as photography. There is hardly a line of investigation which cannot be done more quickly and better by photographic than by visual methods. Nevertheless it would be a mistake to abandon visual observations altogether.

It may hardly need to be stated that for the most part scientific observations of total eclipses have for their object the promotion of our knowledge about the sun. No one, who understands at all how intimate is our dependence upon that great body, will question the wisdom of such efforts. In order to understand why certain problems can be better studied when the sun's face is covered by the moon, it may be well to outline our knowledge on the subject.

The sun, the center of our system, is an exceedingly hot, intensely bright, highly condensed, gaseous body. Its distance is a little less than 93,000,000 miles. Its volume is more than a million times that of the earth. Its specific gravity is somewhat greater than that of water. A gaseous body, denser than water, is something very different

from our ordinary conception of a gas. That which we see, which gives the sun its apparent size, which sends us our light, is known as the photosphere. This is probably a brilliant shell of metallic clouds floating in an atmosphere of vapors of the same materials. There are certain details in this photosphere with which we are familiar, such as bright patches, known by different names, and sun-spots. For convenience we may regard this photosphere and all that it contains as *the Sun*, and all that lies outside this shell as the solar *atmosphere*. With the sun itself we have little to do in this article, since it can be better observed on any clear day than at time of eclipse. It is, however, only at time of total eclipse that we clearly see all those strange and complex features which make up what we have called the solar atmosphere. In our study of it, however, we must not be governed too much by any analogy with our own atmosphere. Lying next to the body of the sun is a layer of crimson flame, known as the chromosphere, which has a thickness of perhaps 5,000 or 6,000 miles. This may seem like a great depth for such a sea of fire, but compared with the enormous size of the sun it is very small indeed, and forms but a thin rose-colored rim about the edge of the sun. At the bottom of this is probably the so-called reversing layer. The solar spectrum is crossed by dark lines due to the elements which there exist. By these dark absorption lines, which are seen in the ordinary solar spectrum, the presence is known of many familiar elements. The higher regions of the chromosphere are less complex and consist in large part of hydrogen. From these regions, by forces which there operate, great masses of brilliant colored gas are thrown upward to enormous distances, in general 10,000, or 20,000 miles, but often much higher, even to 200,000 or 300,000 miles. Resting also on the photosphere is the corona, which extends its pearly light outward from the sun to immense distances which must be reckoned in millions of miles.

The different parts of the solar atmosphere are brightly luminous, and stand forth in splendid beauty at the instant of totality. The only reason why we do not see them on any clear day is that they are lost in the blinding light of the central sun. The sun's face must be shut out. This service is rendered by the moon at an eclipse. At other times the chief trouble is not that the sun shines directly into our eyes, since a piece of cardboard could be so placed as to cut off the rays. The real difficulty arises from the presence of our atmosphere, which becomes so bright from the diffused light of the sun, that the solar appendages are lost to view. This will be apparent from the daily phenomenon of the appearance by night, and the disappearance by day, of the stars. They are shining just as brightly by day as by night, and could be seen perfectly well if the atmosphere were removed for a moment.

One of the most successfully observed of recent eclipses was that of May 28, 1900. The duration of totality was only two minutes, but almost perfect weather prevailed everywhere. It was visited by a large number of skilled observers, and an examination of the work performed and attempted will give a good idea of what astronomers at the present day hope to learn about the sun at times of total eclipse. As stated above, the ordinary solar spectrum consists of a bright band crossed by dark absorption lines due to a reversing layer present in the chromosphere. At the eclipse of 1870, Professor C. A. Young, who was watching the spectrum of the fast disappearing sun, saw, at the instant when the last bit of the photosphere was covered by the moon, the solar spectrum with its dark lines replaced by a spectrum composed of bright lines. This phenomenon, from the suddenness of its appearance became known as the 'Flash.' The 'flash' spectrum is one of the most interesting features of a total eclipse. The depth of the flash layer is very small, and the duration of its greatest intensity very brief, since it is covered by the moon after two or three seconds. To obtain good photographs of this phenomenon is somewhat difficult. This has been accomplished, however, at the eclipses of 1896 and 1898, and, especially, by several observers, at the eclipse of 1900. Several kinds of spectroscopes are in use. Ordinarily an astronomical spectroscope consists of a telescope, a narrow slit, a train of prisms, and a small telescope which brings the spectrum to the eye or to the photographic plate. When the object which is to be examined has an area like the sun the use of a slit cannot be avoided. When the source of light is a point, or a narrow line of light, there is no such necessity and the more simple apparatus, known as the slitless spectroscope, or objective prism, may be used. This consists of a prism placed over the lens of the telescope and a photographic plate at the focus. Instead of the prism or prisms a diffraction grating may be used. Professor Pickering, the director of the Harvard Observatory, has obtained for many years fine spectra of the stars by this method, which is an adaptation of the original method of Fraunhofer. An apparatus of this sort used in eclipse work is known as a 'prismatic camera.' It is evident that this form of spectroscope could not be successfully used on the uneclipsed sun, since the resulting spectrum would be simply a confused mass of colored light. There must be a slit, but in the case of total eclipse, nature furnishes it. As the moon at such times has an apparent diameter greater than that of the sun, it is readily seen that at the instant before the moon's disc completely covers the sun there will remain a very narrow crescent of light. At the instant after totality has begun the photosphere will be entirely covered, but for two or three seconds the thin line of chromospheric light remains in view. The two spectra taken at these moments, the one an instant before

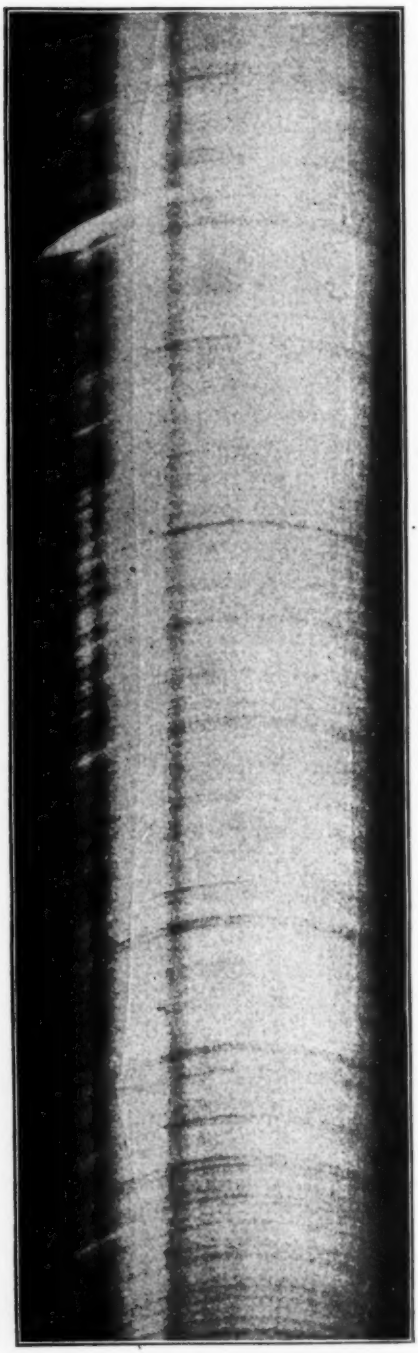

FIG. 1. SOLAR SPECTRUM, 10s AFTER TOTALITY, ENLARGEMENT. MADE BY PROFESSOR E. B. FROST. ECLIPSE OF MAY 28, 900.

FIG. 2. FLASH SPECTRUM AT SECOND CONTACT. MADE BY PROFESSOR FROST. ECLIPSE OF MAY 28, 1900.

and the other an instant after, the beginning of totality have been called the 'cusp' and the 'flash' spectrum. A similar pair occur, of course, when totality ends, but in reverse order. Figure 1 shows an enlargement of a portion of the cusp spectrum at third contact. This photograph was made by Professor E. B. Frost, of the Yerkes Observatory, at the eclipse of 1900. It furnishes an opportunity to compare directly the dark lines of the ordinary solar spectrum with the bright lines of the chromosphere. It is of the greatest interest to learn whether the two series of lines are identical, in whole or in part, though reversed, and in any case to study the characteristics of these bright lines. This photograph was made about ten seconds after the end of totality. The thin line of the photosphere, which had then emerged from behind the moon, was drawn out by the prism into the bright band, which constitutes the larger portion of the picture. This is the ordinary solar spectrum. It will be noted that while in spectra as usually seen the lines are straight, since a straight slit is used, here the lines are arcs, since nature furnishes a crescent of light. An examination of these dark arcs shows that in nearly all cases they become bright lines at the upper edge of the spectrum. This 'reversal' is due to the fact that just beyond the point where the crescent of sunshine ceased, was a small extension of the chromosphere, which was not covered by the moon. The precise determination of all the facts, which this and other similar photographs teach, is one of the important problems of total eclipses. The problem is somewhat complicated, as pointed out by Professor Frost; for although few dark arcs can be seen which do not terminate in a bright tip the curvature and position appear to be slightly different in some cases for the bright lines. Figure 2 shows the 'flash' spectra made at the second contact, that is, at the beginning of totality. The sun is entirely hidden by the moon, and all the lines which appear are doubtless due to the chromosphere. Certain irregularities, or 'bunches,' in the arcs, however, are due to solar prominences. From an examination of these and other photographs Professor Frost has measured and identified several hundred lines, and has reached the following conclusions: "At least 60 per cent. (and probably many more) of the stronger dark lines of the solar spectrum are found to be bright in a stratum not exceeding (for the majority of the lines) 1″, or less than 500 miles in height above the solar photosphere. There is moreover no reason in general to suppose that this is not equally true of the fainter lines. Therefore we may regard the existence of a reversing layer at the base of the chromosphere as fully confirmed by the photographs." These results are especially important since they contradict to some extent those which have been previously obtained. While the elevation of the strata which produce the most of the lines is less than 500 miles, the height of other gases

above the photosphere is as great as 4,000 miles. The bright lines are identified as belonging to iron, titanium, chromium, hydrogen and other elements. The origin of some of the lines is unknown.

Although no other time may be so favorable for the study of the reversing layer as at total eclipses, the chromosphere and prominences may nevertheless be well studied on any clear day.

In connection with the eclipse of 1868 Janssen and Lockyer each independently discovered that by spectroscopic means the light of the chromosphere and prominences may be so separated from that of the sky as to become visible without an eclipse. The light from the region just outside the sun's limb is composed of skylight and the light of the solar atmosphere. Each is about equally bright. When this combined light is passed through a prism, that due to the sky is spread out into a continuous surface, thus becoming much fainter, while that due to the chromosphere or prominence, from its gaseous nature, is collected into bright bands, which thus surpass the skylight in intensity and may be seen or photographed. This line of work has been

FIG. 3. GREAT ERUPTIVE PROMINENCE. WITH HALE SPECTROHELIOGRAPH. MADE MARCH 25, 1895, 10h. 34 m. A.M.

FIG 4. GREAT ERUPTIVE PROMINENCE. WITH HALE SPECTROHELIOGRAPH. MADE MARCH 25, 1895, 10h. 58m., A. M.

greatly extended by different scientists, notably by Hale, of this country, who, by a device known as the spectro-heliograph, has succeeded in making, without an eclipse, photographs showing all the prominences surrounding the sun and the details of the solar surface at the same time. These photographs are made in monochromatic light. They represent what would be seen if the eye were sensitive to light of the wave-length of the K line only. Figures 3 and 4 show a great eruptive prominence photographed by Professor Hale, March 25, 1895. The interval between the two photographs was 24 minutes, during which time the prominence was thrown upward from a height of

135,000 miles to 281,000 miles. This implies a velocity of at least 100 miles per second.

At times of total eclipse it is perhaps possible to obtain better photographs showing finer details than can be made under other conditions. Figure 5 is an enlargement of a photograph made at the eclipse of 1900, by Professor E. E. Barnard, assisted by Mr. G. W. Ritchey. It shows a mass of prominences at the southwest quadrant of the sun. Along the irregular limb of the moon, which appears black, is seen the ragged storm-tossed surface of the chromosphere, of increasing depth toward the right owing to the moon's position at the instant of the exposure. Thrown up from this are the vast, fantastic masses of the prominences or 'red flames.' They remind us of pictures which show the effects produced by the explosion of submarine torpedoes. The larger mass at the left rises to the height of 60,000

FIG. 5. SOLAR PROMINENCES. ECLIPSE OF MAY 28, 1900. PHOTOGRAPHED WITH A TELESCOPE OF 6 INCHES APERTURE AND 6½ FEET FOCUS, BY PROFESSOR BARNARD AND MR. RITCHEY.

miles. This photograph was made with a telescope of only six inches aperture and six and a half feet focal length, a small instrument compared with some which have been used at recent eclipses. The writer has seen no other photograph of prominences, however, which, in delicacy of detail, surpasses the one here shown.

The single feature of a total eclipse which can be seen and studied only at such times is the corona. In early ages small mention was made of the corona. Apparently the dread of impending evil overwhelmed man, and prevented careful observations. As fear disappeared and scientific interest grew, attention was drawn to the 'red flames,' and at nearly the same time to the beautiful halo of light which has been fittingly named the 'corona.' Since that time the favorable moments of totality have been too few to clear up the mystery of its nature. Reasoning from the methods which have made the study of the chromosphere and prominences possible without an eclipse, various attempts have been also made to thus observe and photograph the corona. The simplest way would be by direct vision or photography. There is no doubt but that, if we could remove for a moment the earth's atmosphere, whose glare interferes with our vision, we

should be able to see the chromosphere, prominences and corona without any artificial aid. The brightness of the inner corona is about the same as that of the ordinary sky near the sun. If then one could find

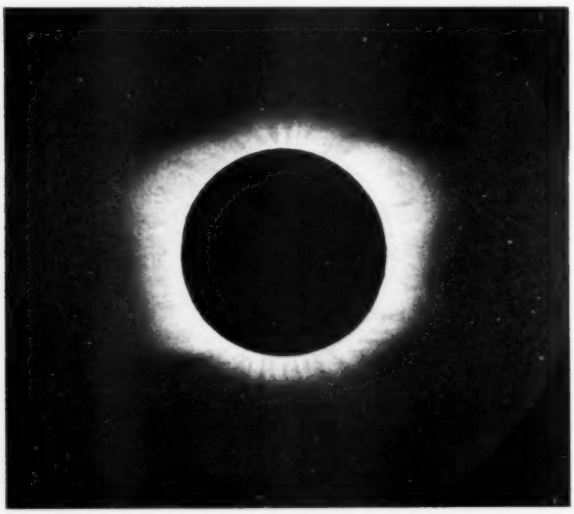

FIG. 6. SOLAR CORONA. ECLIPSE OF 1889. NEAR SUNSPOT MINIMUM. HARVARD ECLIPSE PARTY, WILLOWS, CALIFORNIA.

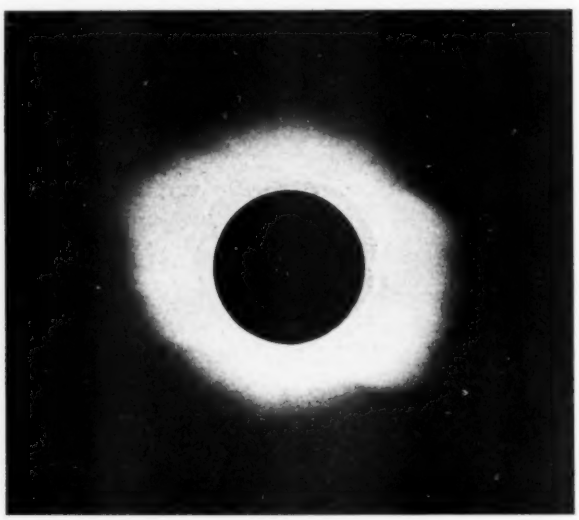

FIG. 7. SOLAR CORONA. ECLIPSE OF 1900. NEAR SUNSPOT MINIMUM. MADE BY MR. C A. R. LUNDIN AT SOUTHERN PINES, N. C.

a locality where the sky was extraordinarily clear, he might hope, by placing a shield in front of the sun itself, to see these fainter features. The writer of this article made an attempt several years ago in this

way on the summit of El Misti, Peru, at an elevation of 19,200 feet. At this altitude one-half the earth's atmosphere is below the observer and that which remains is of extraordinary clearness. Photographs were made of the region immediately about the sun, using an opaque disc to protect the plate from the sun's direct image. The true corona did not appear upon the plates. Other methods promised better results, such as the use of monochromatic light, presumably that of the line 'K 1474.' Experiments in this line have been carried on by Professor Hale with skill and enthusiasm on the summit of Pike's Peak, on Mount Etna and elsewhere, but without success. He has also attempted to solve the difficulty by a study of the heat, using the bolometer. Recent investigations given below explain the failure

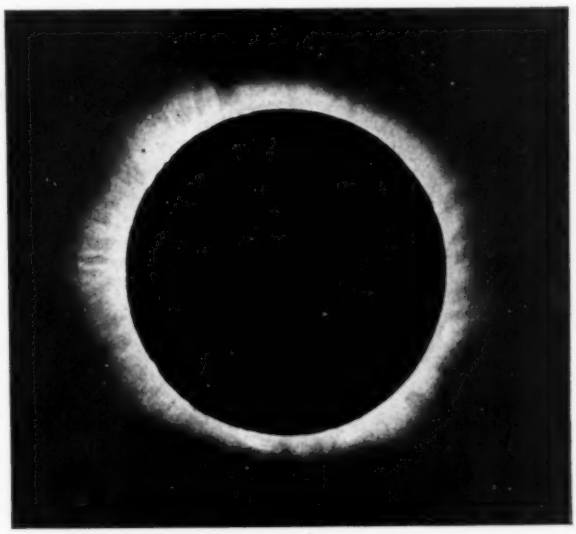

FIG. 3. SOLAR CORONA. ECLIPSE OF 1893. NEAR SUNSPOT MAXIMUM. MADE BY PROFESSOR J. M. SCHAEBERLE, LICK OBSERVATORY.

of this method. The polarization of the coronal light also suggests a method which has not yet yielded successful results. Although the future may furnish the solution, none of the attempts yet made has been successful, and for the present our only knowledge of the corona must be obtained from what can be learned during the brief moments of total eclipses. Good photographs of the corona can be easily and rapidly made and if an abundance of these were alone necessary our knowledge would be well advanced. The general features of the corona have a certain permanence. Comparatively slight changes are known to take place during the three or four hours while an eclipse is passing over the surface of the earth. There may be, however, finer details than are shown on the best photographs yet obtained, which

would give witness to more rapid changes. From year to year large changes in the form of the corona occur and these appear to be associated with the sun-spot period. This is a natural inference, especially since the solar prominences are thus associated. This is well shown by a comparison of the form of the corona in 1889 and 1900, which occurred near the sun-spot minimum, with the form in 1893, which was near sun-spot maximum. These are given in Figures 6, 7 and 8. The equatorial streamers and the divergent polar streamers are much more pronounced at the time of sun-spot minimum. At maximum the corona is more nearly circular. The polar streamers are beautifully shown in Figure 9, a photograph made by the eclipse party, which was under the direction of Secretary Langley, of the Smithsonian Institution. The true nature of the corona and the complex changes which it undergoes are unknown. The spectroscope is the magician's wand which science generally uses to reveal the constitution of unknown objects, but in this case the revelation is only partial. In 1869 Professor Young found the spectrum to be characterized by a bright line in the green, which he identified as Kirchhoff's line 1474. The unknown substance which produces this line has been given the name 'coronium.' There are also other less conspicuous bright lines. When the name 'helium' was assigned to the origin of certain lines in the solar spectrum, no such terrestrial substance was known. Later it was found by Ramsay. A similar issue for coronium would be very acceptable. The corona also yields a faint continuous spectrum, in which Janssen and others have reported certain dark lines of the solar spectrum. This signifies, that in addition to luminous gases, giving a spectrum of bright lines, the corona contains some substance, like a cloud, which is capable of reflecting ordinary sunlight. A part of the light appears to be polarized. It is thought by some observers that there is also a bright continuous spectrum free from dark lines. If true, this would imply a three-fold origin to the coronal light. For the explanation of the corona we have the diffraction theory of Hastings, the mechanical theory of Schaeberle, the magnetic theory of Bigelow, and others. The complete solution of the problem is of the greatest difficulty and of the greatest importance. At the eclipse of 1900 some experiments with that remarkable instrument, the bolometer, appear to throw new light on this subject. These experiments were made by Secretary Langley's chief assistant, Mr. C. I. Abbott, who reached the following conclusions:

These observations indicate not only that the coronal radiation is very slight, but that the *apparent* temperature of the inner corona is below 20° C. For it will be noticed that the bolometer *lost heat by radiation to the corona,* as evidenced by a negative deflection. Hence, when we consider its visual photometric brightness at the point where the bolometric measures were taken,

which, judging by the results obtained by several observers during the eclipses of 1870, 1878, and 1898, was at least equal to that of the full moon, it is difficult to understand how the light of the corona can be due largely to reflection of rays from the sun, or even to the incandescence of dust particles, for from sources of these kinds, which emit a great preponderance of invisible infra-red rays, the bolometer would have given large positive deflections. . . The important result of a comparison of the radiations of the inner corona, the full moon, and the daylight sky somewhat remote from the sun is that while the three are roughly of equal visual brightness, the corona is effectively a cool and far from intense source, while the moon and sky are effectively warm and many fold richer in radiation. Hence it would appear plausible that the corona merely sends out visible rays and that its light is not associated with the great preponderance of long wave-length rays proper to the radiation from bodies at a high temperature. If this be so the coronal radiation might be compared with that from the positive electrical discharge in vacuum tubes, in which, as researches of K. Angstrom and R. W. Wood have shown, there is neither an infra-red spectrum nor a high temperature.

FIG. 9. SOUTH POLAR STREAMERS. ECLIPSE OF 1900. PHOTOGRAPHED WITH A TELESCOPE OF 135 FEET FOCAL LENGTH BY MR. SMILLIE, OF THE SMITHSONIAN ECLIPSE PARTY.

These conclusions are of so great importance that it is very desirable that the observations upon which they depend should be repeated at other eclipses. It is, therefore, very unfortunate that Mr. Abbott at the recent eclipse at Sumatra was prevented by clouds from carrying out the observations which he had traveled so far to obtain. Other observers, however, were no more fortunate. Professor E. E. Barnard was provided with a telescope of 61½ feet focus, and with plates forty inches square, but was prevented by clouds from obtaining results of much value. This was the fate, also, of many other observers from different countries, who had taken stations in different parts of Sumatra. Results of value were obtained, however, by the party from the Massachusetts Institute of Technology, whose photographs of the corona are unsurpassed. At the Island of Mauritius, also, the English astronomers obtained valuable results. As a whole

the eclipse of 1901 probably failed to add much to our knowledge of the sun.

Aside from the problems relating to the sun's constitution, there is still outstanding the question as to the existence of an intra-mercurial planet. This problem can be studied to much greater advantage at total eclipses than at other times. Photographic charts can be made of the whole region about the sun during totality. An examination of several sets of such photographs, taken at different eclipses, should confirm or refute the existence of such a planet. For greater certainty the sky should be photographed in duplicate at each eclipse. Although sufficient material for the decision of this question could apparently be accumulated rapidly, this has not yet been accomplished for a variety of reasons. At the eclipse of 1900, several parties were provided with apparatus especially planned for this work. The weather was everywhere perfect, but accidents of one kind or another affected the results. The Smithsonian party, however, obtained photographs, one of which showed stars fainter than the eighth magnitude. Several suspicious objects were found on these plates, which remain unconfirmed, owing to the failure of other attempts. This and other questions, which, it was hoped, would be decided by the eclipse of 1901, must await some later eclipse for their solution.

To-day, although much is known about the sun, its deeper secrets are yet unraveled. The foundations of physical science appear, indeed, to be somewhat shaken. It is hinted that molecules and atoms are, after all, but 'convenient fictions,' signifying, perhaps, that the human mind is not capable of grasping the ultimate conditions of matter. We hear of corpuscles, which are inconceivably small 'fragments of atoms.' These corpuscles are carriers of electricity. It may be that in this line lies the explanation of many terrestrial, solar, and even cosmical, phenomena.

FRIAR BACON
Engraved from the Original Picture in the Collection at Knole
Pub. May 1 1796 by Richard Godfrey, N°20 Long Acre

FRIAR ROGER BACON.

By EDWARD S. HOLDEN, LL.D.

A RECENT perusal of the published works of Bacon leads me to attempt to set forth, in this place, something of his life and of his times. He is, beyond a doubt, one of the great illustrations of our race. Let us in the first place set down the facts of his checquered life in a story, without seeking too deeply for the causes of his defeats and perils. It will be time enough to examine the reasons when we know the results. He was born of a good and wealthy family, in England, between the years 1210 and 1215. He first appears in history in the year 1233. King Henry the Third had just listened, at Oxford, to a long sermon and to reprimands from a relative of Bacon's—probably an uncle—who charged the king to dismiss from his council Pierre Des Roches, Bishop of Winchester, who was hated by the English. A young clerk—it was Bacon—dared to address the king with this audacious raillery, says Matthew Paris in his chronicle.

"Seigneur Roi, savez-vous les dangers qu'on a le plus à redouter quand on navigue au-delà de la mer?

"Ceux-là le savent, répartit Henri, qui ont l'habitude de ces voyages.

"Eh bien, je vais vous le dire, reprit le clerc, ce sont les *pierres* et les *roches*—et il voulait désigner par là *Pierre* Des *Roches*, l'évêque de Winchester.'

Bold and reckless speaking regardless of consequences was a life-long characteristic of Bacon, and the first and only anecdote that we have represents him bold with kings, as he afterwards was bold towards popes, cardinals, generals of his order, doctors of the church and the society in which he lived. It may, for a moment, seem to us to be a merit. In sad fact, it was never so in his life, and it led to his undoing.

He learned this temerity from a great man who was his master at Oxford and afterwards the illustrious Bishop of Lincoln, Robert Grossteste, the first English scholar of his time—he who browbeat the pope and called him 'heretic' and 'anti-Christ.' Robert was Superior of the Franciscans at Oxford and lectured there on optics. Athelard of Bath, the first translator of Euclid, was not forgotten in those schools, which were then marked by great intellectual freedom and by a strong leaning towards science.

Here Bacon passed years in ardent research. He mastered all the book learning of the schools—philosophy and mathematics; and ex-

pended, he tells us, something like £2,000 (probably French pounds) in his experiments in natural philosophy, chemistry and astronomy. Experimental science was a new thing and Bacon may well claim to be its founder, though Ptolemy experimented on refraction, Galen on the nerves and muscles and the Arabs in various branches of science.

About the year 1240 Bacon became a friar of the order of St. Francis. If he had seen clearly, his career was made. Albertus Magnus and his great pupil, Thomas Aquinas, were the lights of the Dominican Order. The Franciscans would have welcomed and honored a champion who was the superior of Albert and the equal, or almost the equal, of Aquinas. But Bacon had only rough and bitter criticisms for all monks—Franciscans and Dominicans alike. His was an original and hardy genius; and he proved himself a merciless critic of all celebrities, of every accepted method and conclusion. Alexander of Hales, *Doctor Irrefragabilis,* was the oracle of the Franciscans. Of his *Summa Theologiæ,* Bacon says: It was a load for a horse—true—but—the reputed author did not write it. Albertus Magnus wrote libraries of books: All of them that were of any account, says Bacon, could be put in a single volume. Aquinas is *vir erroneus et famosus.* Of the other doctors, Michael Scot, he says, knew no Greek, Gerhard of Cremona, not even Latin, and William of Morbecke, the friend of Aquinas, was the most ignorant of all. St. Augustine and Origen were full of errors, and St. Jerome did not always understand the scriptures he translated.

"Never was there so great an appearance of wisdom, nor so much exercise of study as for this last forty years. Doctors are everywhere, in every castle, in every burgh, especially the students of the two Orders (Franciscan and Dominican). And yet there never was so much ignorance and error." He condemned the current versions of Aristotle—retranslations from the Arabic of translations once made into Syriac by Nestorian monks. "The common herd of students," he says, "mope and make asses of themselves over their bad translations and waste their time, their trouble and their money." In fact, he declares, "What the mass of men believe is necessarily false." As for the works of Aristotle, he would burn them all.

It is no wonder that Bacon was disciplined and imprisoned in Paris during the years 1257 to 1267. How severe his punishment was we shall never know. A part of it was rigorous. He was forbidden books and copyists, kept on bread and water. At times, however, he had pupils, copyists and some slight degree of liberty. He was condemned by a council of his order *propter quasdam novitates suspectas*—in reality because his harsh and innovating spirit diffused uneasiness all about him. It is charitable if we do not pronounce him envious. With Albertus Magnus and Aquinas he made up a trio of really great men,

but he has no good words for either of them or for their works and ways. The men of no century have listened willingly to criticism delivered in this temper. That his strictures were substantially just did not make them more acceptable in Bacon's case, nor four centuries later, in the case of Galileo. It was of no avail that his life was pure, that he had not sinned against the faith, that he had not rebelled against authority. His real offence was the censorious temper which made him enemies on every hand.

A new opportunity came to Bacon with the election of Guy Foulques (Clement IV.) to the papacy. The new pope had been a soldier, a learned jurisconsult, and Secretary of Saint Louis, before taking religious orders. While he was legate of the reigning pope in England he heard that Bacon was writing a treatise on the reformation of learning, and on many occasions he endeavored to communicate with him by letters which were intercepted by the Franciscans. In the second year of his own pontificate (1266) the new pope, Head of the Church, succeeded in sending a letter to Bacon by private hand. The letter orders Bacon "in the name of our apostolic authority and notwithstanding any injunctions to the contrary from any prelate whatsoever, and notwithstanding the constitution of your Order, to send, without delay, a copy of the work for which we asked at the time of our legation into England"; and the pope especially charges his correspondent that all this should be done "with all the secrecy possible." What a commentary upon the strictness of Bacon's imprisonment is this letter from the Head of the Church, the successor of St. Peter, with power to bind and loose! If it exhibits the persecution of Bacon, the power of the Orders, the penances of fasts and macerations, the misery of the prisoner, it also exhibits in the best and strongest light the existence in the Church of enlightened and generous spirits. Everything in the picture is not dark.

Bacon was released in 1267 by order of the pope who had then received his *Opus Majus,* and he returned to Oxford to find his group of noble friends dispersed or dead. Here he resumed his studies, his writings, his criticisms, his bitter and censorious polemics.

His protector, Clement IV., died in 1268 and the new pope soon had good reason to distrust the English friar. Bacon vehemently attacked the orders, the pope, the court at Rome, the prelates, the laïcs, the clerks, the doctors of the Church, the theologians. He swept the world clean of friends and followers. "Consider," he says, "every rank of society and you shall find an infinite corruption everywhere, beginning at the summit. The court at Rome is dominated by the Civil Law * * * this sacred seat is the prey of crime and deceit, justice is perishing, peace is violated, pride reigns, avarice burns there, gluttony corrupts manners, envy eats their hearts, luxury

dishonors the entire Court of the Papacy. * * * And the prelates! consider how eager they are for riches, how indifferent to the care of souls, * * * The religious (of the orders) are no better, and I except no Order whatsoever. * * * This people of clerks are a prey to pride, luxury and avarice. Everywhere, as at Paris and Oxford, they scandalize the laïcs * * * by their vices."

What remedy for this horrible state of things? What examples of holy living and dying does Bacon put forth for imitation? Why, the ancients like Zeno and Seneca, pagans all, and infidels like Avicenna, Alfarabius and the rest! We seem to hear the murmurs of the Renaissance in the words of this monk of the thirteenth century. If the church will not purge herself of evil he predicts the coming of the Tartars or the Saracens. In reality he was foretelling the Reformation. Terrible words like these led to his own imprisonment, again at Paris, in the year 1278. This time his punishment was strict. He was not released until a liberal general of his Order sent him home in 1292, an old man of some eighty years, to die in peace at Oxford.

The story of his life is told. Henceforward we are concerned only with the debt which modern science owes to him. But there are two errors into which we must not fall. In the first place those dark ages were not without illumination. Consider the group of great and liberal men who were Bacon's companions at Oxford in his early years, and that other group of free spirits at Paris. Consider the patience with which a pope tries for years to lighten his lot and the generosity with which he sets him free at last. Consider that the same history is almost exactly repeated by the enlightened general of his order who releases him in 1292.

And, again, let us see what were, in all likelihood, the suspect novelties for which he was punished. Like all the great and small of his time Bacon believed in astrology—in the influence of the stars upon the destinies of men. Was not christianity itself ushered in by the portent of the Star of Bethlehem? An idea adopted from the Arab Albumazar, that the advent and continuance of religions depend upon the conjunctions of the planets, was his ruin. Christianity came in, he said, with a conjunction of Jupiter and Mercury, and all religions were to disappear at a future conjunction of Jupiter and the moon. This is the suspect novelty for which he was condemned by a chapter of his order; and who shall say that he was not justly condemned? If it were allowable in a superstitious age to cast horoscopes and to reckon up the influence of stars upon the fate of individuals, it would have been monstrous and suicidal for the church to agree that religions were subject to purely natural laws and conjunctions. No church could fail to strike home when threatened with

extinction in this material fashion. Bacon is no martyr of science. He was punished for an attack on the very nature and existence of the church itself; for setting up a natural law to govern and limit the things of the spirit.

Owing to the horror which was felt by the writers of that age for the heresies of Bacon, his influence was very small. While Albertus Magnus was entertaining kings, and while Aquinus was the honored expounder of ecclesiastical doctrine, their contemporary and peer was languishing in confinement. His immense work was done in spite of his disgrace. His pupils received his doctrines and through them his ideas gained currency. His writings are scarcely mentioned by the authors of the fourteenth and fifteenth centuries, but we know of at least three cases in which they exerted a profound influence. The admirable doctrine of optics set forth in his work on perspective was known to Descartes, beyond a doubt, and cannot have failed to direct the thoughts of the philosopher to whom we owe the foundation of our modern theories. Again, Paul of Middleburg was deeply concerned with the reform of the calendar, and in his treatise on the subject made great use of Bacon's writings. It was Paul that suggested to Copernicus the need of more accurate tables of the planets, and we may fairly say that Bacon's labors came to fruition in the heliocentric theory of the world. Finally, a long passage in his *Opus majus,* treating of the probable proximity of Spain and India, was literally transferred (without credit) to the Imago Mundi of Peter d'Ailly. It is Columbus himself, in a letter to the King and Queen of Spain, who cites this passage as one of the authorities that put it into his mind to venture on his great voyage. Truly ideas do not die, and those of Bacon have made great changes in this little world of ours.

We may pass over his influence upon the metaphysical controversies of his time, though it was not small. He was thoroughly versed in scholastic dialectic and was much concerned to combat the pantheistic theories of Averroës and his school. He is of the strictest sect of the Nominalists, with a reasonable practicality all his own. "The prevalent view," he says, "is that universals exist only in the mind. Yet two stones would be like one another even though there should be no mind to perceive them. But it is precisely this likeness of the two stones that constitutes their universal." How modern it sounds! How crisp and neat, like a French logician. With Bacon as with others whom we call the ancients, we perpetually meet the modern note. *A man's character is his fate* was not written by Taine or Stendhal, but by Heracleitus five centuries before the Christian era.

Bacon proposed to Clement IV. the reform of the calendar in sagacious and artfully presented terms. He points out to the pope the errors of the accepted lunar tables, and proves that after a series

of years the moon will be a full moon in the sky, but a new moon in the calendar. Nothing could be neater than the presentation of this dilemma.

Bacon understood the theory of vision, the anatomy of the eye and much of the physiology of perception, as well as the theory of lenses and of the simple microscope. He did not combine two lenses to make a telescope, but he was on the high road to it. His works on alchemy were undertaken in the same scientific spirit, though in the infancy of chemistry they led to few results of value. Gunpowder he knew, very likely through the Arabs or the Greeks of Constantinople, who had it from the east. The children of his time played with it, he says.

No better example of the experimental method imagined and extolled by Bacon can be given than an analysis of his brilliant demonstration of the nature of the rainbow. Let the experimenter, he says, first consider the cases in which he finds the same colors; as in the hexagonal prisms of Iceland spar, for example. By looking into these he will see the rainbow hues. Many think that these arise from some special virtue of the stones, or from their hexagonal figure. Let the experimenter therefore go on and he shall find the same colors in other stones of other shapes, as well as in the drops of water dashed from oars in the sunshine, and the like. All these are instances like the phenomenon of rainbow colors. With regard to the form of the bow he is still more precise. He bids us measure the altitude of the bow and of the sun and note that the center of the bow is exactly opposite to the sun. He explains its circular form—its independence of the form of the raincloud—its moving when we move—its flying when we follow—by its consisting of reflections from a vast multitude of minute drops of rain. In the iris shown by the spray of a waterfall we may see the whole circle. In the sky the plane of the horizon comes in to interfere. Each drop of rain in the cloud is to be regarded as a spherical mirror.

His views of the nature of force are expansions of those held vaguely by Democritus and Lucretius. A body is a center of force from which energies radiate in every direction. Every action is accompanied by a reaction, and there is an interchange of force between all bodies of the universe. The propagation of force, of light for example, requires time. "There is no substance on which the action involved in the passage of a ray may not produce a change. Thus it is that rays of heat or sound penetrate the walls of a vessel of gold or brass. In any case, there are many dense bodies which altogether interfere with the visual and other senses of man so that rays cannot pass so as to produce an effect on human sense and yet, nevertheless, rays do really pass, though without our being aware of it." These precise statements were mere words to his contemporaries and could not

have been completely understood before the beginning of our own century. The note is that of Count Rumford or, at earliest, of Newton and Huyghens.

That learning might be reformed, he proposed the study of the comparative grammar of Greek, Arabic, Latin and Hebrew, the assiduous collection of ancient manuscripts and the ardent study of the classics. Here is the distinctive note of the Renaissance. But if the study of ancient books be so important how much more imperative is the study of the book of Nature!

> I call experimental science, says Bacon, that which neglects argumentation; for the strongest arguments prove nothing so long as they are not verified by experience.
>
> Experimental science does not receive truth from the hands of the higher sciences; it is she who is the mistress; the others are but her handmaids.
>
> She has the right to command; for she alone certifies and consecrates their results.
>
> Experimental science is then the Queen of the sciences and the limit of all speculation.
>
> Physicists should know that their science is impotent if they do not utilize the power of mathematics, without which observation grows weak and incapable of any certitude.

These sentences selected at random out of whole chapters epitomize the teachings of Francis Bacon three centuries later and bring us near to the viewpoint of Helmholtz or Lord Kelvin.

Bacon had already begun the application of his absolutely new method and he has a clear vision of what may be accomplished in the future. After the mere facts of nature are discovered, he says, the laws back of the facts will be brought to light. When they are once known, the work of speculation will be completed. Man is to be the master of the world and his will is to govern. "Machines will be invented to navigate the seas without rowers; to traverse the land with unimaginable velocity; to fly with artificial wings; to walk on the bottom of the seas without danger; to bridge rivers without piers or columns." We are yet very far from a complete conquest of nature, but the nineteenth century has seen the accomplishment of each of these visions of the astonishing monk of the thirteenth.

The entire work of Bacon is summed up in two insights of widely different character and of the first importance. Either of them is a title to enduring fame. He was the first of men to expose the essential infertility of scholastic philosophy; and he was the originator of the inductive methods that characterize modern science. If we set down in detail the matured judgments of our own time upon the scholasticism of the thirteenth century we shall find that each and every one of them was fully anticipated by Bacon; that he clearly

saw all its weaknesses and defects; and that he enforced his insight by constant, bold, vigorous and searching criticism. If we analyze the scientific methods of Galileo, Huyghens and Newton we shall find that, in their large lines, they are the same as those of the Experimental Science based upon mathematics, of which Bacon was the first inventor and almost the only exponent for three hundred years

The thirteenth century, as a whole, received its full expression in the works of Albertus Magnus. We can only comprehend the admirable independence and originality of Bacon's mind when we have compared him, point by point, with his great rival. They are literally worlds apart. One epitomizes the old world; the other foretells the new. Seen in this summary way Bacon appears a *lusus naturæ*—as a man born quite out of his own time; and he is usually so regarded. When, however, we consider his whole career with a minuteness that has been impossible in this short sketch, we discover that the seeds of the rich harvest of his mind were sown by his great teacher, Robert of Lincoln; that in Paris Peter of Mericourt—the author of *De Magnete,* from which Gilbert of Colchester derived many of his ideas —was his master in experimental science; and that both in Oxford and Paris he found many kindred spirits. We have proofs, therefore, that in the first half of the thirteenth century there were at least two companies of open-minded and liberal scholars. The fame of Bacon's lectures at the universities testifies to the existence of the same spirit in other large companies. It is only because the annals of the time are so deficient, and especially because the history of that time has been written by the Dominicans, his enemies, that we cannot adduce other specific instances, with names and dates, to demonstrate more fully that Bacon had the fellowship of men of his own stamp; that, in a strict sense he was the highest product of his age; that he was not, at least for half his life, utterly isolated. Until we understand these conditions we cannot comprehend his true relations to his age. At the beginning of the century there was a striving towards sound learning—a veritable revival—of which Bacon is the highest exponent. We are not concerned to here exhibit how and why the spirit of the century changed when its years were half run out.

If his career could have been, like that of Albertus Magnus, molded into a reasonable conformity to the spirit of his time, his works would have also been the text-books of the schools of the thirteenth century; his influence would have been immense and immediate; the revival of learning would have dated from Bacon, not from Petrarch; the foundations of modern science would have been firmly laid three centuries before Copernicus. Why these changes were not to be is explained by his character: and his character was his fate.

LAMARCK, THE FOUNDER OF EVOLUTION.*

By Professor W. H. DALL.

IT is now nearly a century since Lamarck published the outlines of his theory of evolution by descent with modifications transmitted by heredity and initiated by dynamic impulses; originating in the mass of animals from the environment, and in the higher and more intelligent groups partly from within the developing organism itself.

Met by the ridicule and unfriendly criticisms of the 'creationists,' which were the more generally accepted on account of the modesty, retiring disposition and aversion to controversy of Lamarck himself, handicapped by the blindness and poverty of his later years, his views have been little known in their true shape, and the majority of naturalists have been content to receive them in the garbled form in which they were presented by those who rejected them. Theoretical, as the conditions of science at the time made obligatory; in some respects with our present light obviously erroneous; the philosophy of Lamarck nevertheless contained also a body of opinion substantially in harmony with the evolutionary ideas of Spencer and Darwin, and which has been established by the work of modern students of nature, among the axioms of science.

It was then a pious task which Professor Packard undertook, to present in its true form the zoological philosophy of this venerable pioneer, that the present generation of philosophers might learn their obligations to him. To this sympathetic exposition of Lamarck's views the author has prefixed a summary of the meager details in regard to his private life and public services, which a careful search has been able to discover; illustrated them by pictures of the house in which Lamarck was born, and that in which most of his work was done and where he died, adding a facsimile from his manuscript. Finally a chapter has been added in which the revival of Lamarckian ideas among an influential body of modern students is summarized.

Jean-Baptiste-Pierre-Antoine de Monet, Chevalier de Lamarck was born August 1, 1744, at Bazentin-le-Petit, Department of the Somme, near Longueval. His mother was Marie Françoise de Fontaine. His family belonged to an ancient race of the minor nobility of Béarn. On the death of his father in 1760, he joined the French army, then campaigning in Germany. Almost immediately afterward he achieved

* Lamarck, the founder of evolution, his life and work, by Alpheus S. Packard, M.D., LL.D. Longmans Green and Co., New York, 1901. Pp. xiv + 451, 8°, ills.

distinction and was named an officer on the field, for especially gallant conduct at the battle of Fissinghausen in Westphalia. He soon became a lieutenant but an injury inflicted by a brother officer at play obliged him to retire to Paris for surgical aid and to leave the army. He attempted to study medicine, served as clerk in a bank and made himself acquainted with botany to which finally he gave his whole attention under Bernard de Jussieu for some ten years, when he published his 'Flore Française' which gave him at once a national reputation. Through the influence of Buffon he obtained a post in the Academy of Sciences, and, as companion to Buffon's son, traveled on the continent in Germany, Hungary and Holland, visiting museums and making botanical collections. After his return Buffon's successor appointed him keeper of the herbarium in the Royal Botanical Garden with a stipend of 1,000 francs, which was later raised to 1,800 francs. In 1793 the establishment was reorganized as the Museum of Natural History and in the midst of the revolution, under the new conditions the botanist Lamarck was appointed to a professorship of zoology, in charge of the collection of invertebrate animals, the other zoological professorship, involving the care of the vertebrate collections being assigned to Etienne Geoffroy St. Hilaire, a devoted friend of Lamarck and like him an evolutionist. Lamarck, now fifty years old, married a second time, with six children, received a suite of rooms in the Maison de Buffon attached to the garden, and a salary of 2,868 livres. Here he remained, lectured and worked, until blindness overtook him about 1821, when the last volume of the Animaux sans Vertébres prepared from his dictation by his devoted daughter, Cornélie, was presented to the assembly of professors attached to the establishment. He died in the Maison de Buffon, December 28, 1829, and was buried in a temporary grave in the cemetery of Mont Parnasse. His bones, mingled with those of a thousand others, lie somewhere in the catacombs of Paris. To the adversities suffered in life was added the delegation by the academy of the preparation of his memorial *éloge* to Cuvier, his most determined opponent in the ranks of the 'creationists.' While destitute of low malice this memoir, conceived in a spirit of contempt for Lamarck's philosophical theories, has done much to obscure his merits and place him in a false light before posterity. That the present volume may vindicate his reputation and lead to a more impartial estimate of the work of this truly great naturalist and admirable man, may confidently be predicted; as even those who differ from Lamarck's conception of environmental and dynamic factors in evolution must feel obliged to recognize much in other phases of his philosophy which now forms the common property of science, but which Lamarck was among the first to advance and which he maintained steadily, in spite of ridicule and incredulity, to the end of his days.

COMETS' TAILS, THE CORONA AND THE AURORA BOREALIS.

By Professor JOHN COX,

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THERE is undeniable fascination about a theory which includes within its sweep the time-honored problems of astronomy connected with comets' tails and the reason why they point away from the sun; the solar prominences and the corona; the source of the light by which the nebulæ shine; the origin and structure of meteor-swarms; and the aurora borealis; besides solving incidentally half a dozen minor outstanding mysteries of the heavens.

Such a theory has been advanced by Sweden's distinguished chemist and physicist, Svante Arrhenius, in a paper published in the 'Physikalische Zeitschrift' for November, 1900. Its main points were briefly mentioned with approval by no less an authority than Professor J. J. Thomson at the end of his captivating article on 'Bodies smaller than Atoms' in the August number of The Popular Science Monthly. All the physical principles on which Arrhenius relies, with one exception, are explained at length in that article, and are now very generally accepted. We may therefore say that the theory is based on 'veræ causæ,' and its accordance with known facts is so impressive when the comparison is made in detail that I venture to think the readers of Professor Thomson's article will be interested in a more complete statement of Arrhenius' views than time permitted him to give.

Let us begin by taking stock of the physical principles already to hand. We know (Professor Thomson's paper) that corpuscles, about 1,000 times smaller than hydrogen atoms, and each bearing a charge of negative electricity, are discharged with high velocity:

(1) from the negative electrode in a Crookes tube (kathode rays).
(2) from objects struck by kathode rays (Röntgen rays).
(3) from hot bodies, such as glowing metals.
(4) from cold metals under the influence of ultra-violet light.
(5) from the radio-active substance radium.

Again we know that these corpuscles, or *ions*, in passing through a gas produce other ions by collision with the molecules of the gas, and that the negatively charged ions are capable of serving as nuclei for the condensation of ordinary matter.

Comets' Tails.

The single new principle introduced by Arrhenius arises in connection with the problem of comets' tails. Astronomers have always felt that the phenomena exhibited by these strange objects could only be accounted for by making the sun the seat of a violent radial repulsive force, but were entirely at a loss to account for this repulsion. So long as light was supposed to consist of myriads of corpuscles discharged with a speed of 186,000 miles per second, it was easy, with Kepler, to regard the corpuscles as carrying with them in their rush the materials vaporized from the comet by the heat of the sun. But the establishment of the Wave-Theory of light put an end to this idea. Thus Newcomb says ('Popular Astronomy'): "If light were an emission of material particles, as Newton supposed it to be, this view would have some plausibility. But light is now conceived to consist of vibrations in an ethereal medium; and there is no known way in which they could exert any propelling force on matter!"

Now Arrhenius points out that according to the Electromagnetic Theory of light a ray of light *does* exert a pressure on any surface on which it impinges. Maxwell not only proved this in his original publication of the theory in 1873, but showed how to calculate its value. With the known constants of solar radiation he found that sunlight at the surface of the earth should exert a pressure of $.592 \times 10^{-10}$ grams on every square centimeter. This is too small a force to be detected, though it has been looked for.

But at the surface of the sun the pressure would mount up to 2.75 milligrams per sq. cm. On the other hand, a cubic centimeter of water, which weighs one gram at the surface of the earth, would weigh 27.47 grams at the surface of the sun, *i. e.*, the attraction of the sun would draw it inwards with about 10,000 times the force with which the sun's light would tend to drive it away.

Very different is the case if, instead of a cubic centimeter, we consider a much smaller cube. The pressure on its base would fall off as the square of its edge, but the weight would diminish as the cube. There must come a point at which the pressure of the light would just balance the weight; and still smaller particles would be driven off with a force greater than their weight. *They would behave, in fact, as if gravity had become negative.*

For example, a cube of water measuring one-thousandth of a millimeter (10^{-4} cm.) in the edge would weigh 27.47×10^{-12} gms.; and the pressure of light on its base would be $2.75 \times 10^{-3} \times 10^{-8}$, $= 27.5 \times 10^{-12}$ gms., *i. e.*, slightly more than its weight.

In measuring wave-lengths of light physicists denote one-thousandth of a millimeter by the symbol μ. The critical value of the edge of a cube of water, *i. e.*, the value for which its weight is exactly neutralized

by the pressure of light at the sun's surface, is thus approximately μ. For a spherical drop the critical diameter may be calculated to be 1.5 μ for water. For other substances the critical value is inversely proportional to the specific gravity.

A similar effect of extreme minuteness is familiar to us as the explanation of the long time required by very small particles to settle through the atmosphere, amounting to many months in the case of the finely divided dust thrown up during the eruptions of Krakatoa. But the resistance to suspended dust particles can never exceed their weight, since it is only called forth by the motion produced by the weight itself. The pressure of light now considered may enormously exceed the weight provided the particles are small enough.

From the motions, and especially the curvature, of comets' tails the magnitude of the repulsive forces to which they are subject may be calculated. Thus Bredichin finds, in four instances, that the repulsion must have been about 18.5, 3.2, 2.0, and 1.5 times the sun's gravitational attraction. Now the vapors emitted by comets are largely hydrocarbons of specific gravity about .8. To account for these repulsions on Arrhenius' principle, the drops must have had diameters of 0.1 μ, 0.59 μ, 0.94 μ, 1.25 μ respectively. In another case, where the tail curved towards the sun, Bredichin found the repulsion to be 0.3 times gravity. This would indicate particles of diameter 6 μ. Particles of this order of magnitude, and far smaller, are familiar enough to us, especially in combustion and in the early stages of condensation.

The theory suggested is then as follows: As the comet approaches the sun, the intense heat causes a violent eruption of hydrocarbon vapors on the side towards the sun. The hydrogen boils off, and the vapors condense into small drops of hydrocarbons with higher boiling-points, or ultimately solid carbon is thrown out, finely divided as in an ordinary flame. The largest of these particles fall back to the comet, or if they are not condensed till at a great distance from it, they form tails turned towards the sun. The smaller are driven rapidly from the sun by the pressure of its light, with a speed depending on their size, and form the ordinary tails pointing away from it. That particles of different sizes should be formed from the same comet is natural since the comet is likely to be formed of heterogeneous materials, and there must be great variety in the circumstances of condensation. Thus the comet of 1744 had no less than five tails of different curvature. Occasionally the calculated repulsion on the same tail is not found to follow exactly the law of the inverse square of the distance from the sun throughout its whole length. This puzzling circumstance is at once explained, if the particles should for any reason change their state of aggregation, and consequently their size, during their headlong career. In the light of this theory the following passages will be found very suggestive.

(Herschel, 'Outlines of Astronomy,' p. 376.)

"It is for the most part after thus passing the sun, that they shine forth in all their splendor, and that their tails acquire their greatest length and development; thus indicating plainly the action of the sun's rays as the exciting cause of that extraordinary emanation."

Again (p. 566).

"The tail of the great comet of 1680 immediately after its perihelion passage was found by Newton to have been no less than 20,000,000 leagues in length, and to have occupied only two days in its emission from the comet's body! a decisive proof this of its being darted forth by some active force, the origin of which, to judge by the direction of the tail, must be sought in the sun itself."

Now a particle with one-half the critical diameter would in the course of traveling from the sun's surface to a distance equal to his radius acquire a speed of 430 kilometers per second. With this velocity it would cross a space equal to the diameter of the sun, 865,000 miles, in less than an hour. In comets' tails we probably have to do with particles having less than one eighteenth of the critical diameter. Such particles would cover the same distance in less than four minutes. With a force many times the sun's attraction driving them into space, they would make little of 20,000,000 leagues in two days; whereas if this were to be accomplished against gravity the velocity of projection required might well stagger the astronomers.

Referring to Halley's comet, Herschel says (p. 381):

On the 2d of October (*the very day of the first observed commencement of the tail*) the nucleus, which had been faint and small, was observed suddenly to have become much brighter, and to be in the act of throwing out a jet or stream of light from its anterior part, or that turned *towards* the sun. This ejection after ceasing a while was resumed, and with much greater apparent violence, on the 8th, and continued with occasional intermittences so long as the tail itself continued visible. . . These jets, though very bright at their point of emanation from the nucleus, faded rapidly away, and became diffused as they expanded into the coma, at the same time curving backwards, as streams of steam or smoke would do, if thrown out from narrow orifices, more or less obliquely, in opposition to a powerful wind, against which they were unable to make way, and ultimately yielding to its force, so as to be drifted back and confounded in a vaporous train, following the general direction of the current.

It seems impossible to avoid the following conclusions. 1st. That the matter of the nucleus of a comet is powerfully excited and dilated into a vaporous state by the action of the sun's rays, escaping in streams and jets at those points of the surface which oppose the least resistance. 2ndly. That this process chiefly takes place in that portion of the nucleus which is turned towards the sun; the vapour escaping chiefly in that direction. 3rdly. That when so emitted, it is prevented from proceeding in the direction originally impressed on it, by some force directed *from* the sun, drifting it back and carrying it out to vast distances behind the nucleus, forming the tail. 4thly. That this force, whatever its nature, *acts unequally* on the materials of the

comet. 5thly. That the force thus acting on the materials of the tail cannot possibly be identical with the ordinary gravitation of matter, being centrifugal or repulsive, as respects the sun, and of an energy very far exceeding the gravitating force towards that luminary. This will be evident if we consider the enormous velocity with which the matter of the tail is carried backwards, in opposition both to the motion which it had as part of the nucleus, and to that which it acquired in the act of emission.

Again, describing the long straight tail of the great comet of 1843, from which a lateral tail, nearly twice the length of the regular one, was shot forth in a single day, Herschel says:

The projection of this ray, which was not seen either before or after the day in question, to so enormous a length (nearly 100°) in a single day conveys an impression of the intensity of the forces acting to produce such a velocity of material transfer through space, such as no other natural phenomenon is capable of exciting. It is clear that *if we have to deal here with matter, such as we conceive it, viz., possessing inertia, at all*, it must be under the dominion of forces incomparably more energetic than gravitation, and quite of a different nature.

And finally (p. 406):

There is beyond question some profound secret and mystery of nature concerned in the phenomenon of their tails. In no respect is the question as to the materiality of the tail more forcibly pressed on us for consideration than in that of the enormous sweep which it makes round the sun in perihelio, in the manner of a straight and rigid rod, in defiance of the law of gravitation, nay, even of the received laws of motion, extending (as we have seen in the comets of 1680 and 1843) from near the sun's surface to the earth's orbit, yet whirled round unbroken, in the latter case through an angle of 180° in little more than two hours. It seems utterly incredible that in such a case it is one and the same material object which is thus brandished. If there could be conceived such a thing as *a negative shadow*, a momentary impression made upon the luminiferous ether behind the comet, this would represent in some degree the conception such a phenomenon irresistibly calls up. But this is not all. Even such an extraordinary excitement of the ether, conceive it as we will, will afford no account of the projection of lateral streamers; of the effusion of light from the nucleus of a comet towards the sun; and of its subsequent rejection; of the irregular and capricious mode in which that effusion has been seen to take place.

These passages give a vivid picture of the utter puzzledom of astronomers over difficulties which arise from precisely those phenomena which fit most naturally into the theory of Arrhenius.

The Prominences and the Corona.

At the moment when the sun's disc is obscured in a total eclipse enormous red flames, sometimes curving over towards the sun and sometimes floating like clouds at heights up to 40,000 miles above his surface, are seen projecting over the region of sunspots, where the sun's eruptive activity is greatest; and silvery streamers with a radial structure form a lens-shaped envelope about the same region, often extending

to a distance of several times the sun's radius. These are known as the prominences and the corona.

The sun must itself project vapors into space. When these condense, the drops will, if larger than the critical size, fall back to the sun, giving rise to the curved prominences; and if smaller, they will be driven off into space, and be seen as the streamers of the corona. Since the eruptions will not always be perpendicular to the sun's surface, the prominences will often exhibit parabolic curves, and the streamers may not always be strictly radial, though the greater part of this effect is to be attributed to the foreshortening under which some of them are viewed from the earth.

Those particles which have approximately the critical diameter will float as clouds, sustained by *the pressure of light.* This point is specially interesting, since it has been difficult to account for the maintenance of the cloudlike prominences without assuming the existence of a considerable atmosphere about the sun. Yet the comet of 1843 described 300,000 miles within a distance of less than one-third of the sun's radius from his surface with a velocity of 350 miles per second, and came out without having suffered any visible damage or retardation.

The corona has been as great a stumbling-block to astronomers as the comet's tail. Thus Newcomb ('Popular Astronomy,' p. 263) says:

> The corona is not a mass of foggy or milky light, but has a *hairy structure* like long tufts of flax. . . Of this appendage we may say with confidence that it cannot be an atmosphere, that is, a continuous mass of elastic gas held up by its own elasticity. . . What then is the corona? Probably detached particles partially or wholly vaporized by the intense heat to which they are exposed. . . The difficult question which we meet is, How are these particles held up? To this question only conjectural replies can be given.

Three conjectures are then mentioned, of which we may note the first.

> That the matter of the corona is in what we may call a state of projection, being constantly thrown up by the sun, while each particle thus projected falls down again according to the law of gravitation. The difficulty we encounter here is that we must suppose velocities of projection rising as high as 200 miles per second constantly maintained in every region of the solar globe.
>
> The prominences are of two classes—the cloud-like and the eruptive. The first class presents the appearance of clouds floating in an atmosphere; but as no atmosphere dense enough to sustain anything can possibly exist there, we find the same difficulty in accounting for them, that we do in accounting for the suspension of the matter of the corona.

Professor Young is frankly despairing.

> I do not know what to make of the corona. . . By what forces the peculiar radiated structure of the corona is determined I have no definite idea. The analogies of *comets' tails and auroral streamers* both appear suggestive; but on the other hand, the spectra of the corona, the aurora borealis, the comets and the nebulæ are all different, no two in the least alike. . . Nor

have I any theory to propose to account for *the certain connection between disturbances of the solar surface and of terrestrial magnetism.*

The words we have underlined in this passage have almost a Sophoclean irony to a reader acquainted with the further developments of Arrhenius' theory to which we now turn.

The Zodiacal Light and the Gegenschein.

Not only is the sun the source of those eruptions of ordinary matter which form the prominences, but we have every reason to be believe that he must emit streams of electrically charged corpuscles both directly, as a hot body, and indirectly, since the electrical discharges which, according to all terrestrial analogies, must accompany the violent chemical actions going on near his surface, will, when they take place in the higher and rarer regions of his atmosphere, give rise to kathode rays, and these, in turn, to Röntgen rays. As Professor Thomson says: "As a very hot metal emits these corpuscles, it does not seem an improbable hypothesis that they are emitted by that very hot body, the sun."

Now the negatively charged corpuscles are preeminently fitted to serve as nuclei for the condensation of the ordinary matter. Hence those particles of the latter which, having more than the critical diameter, fall back to the sun, will carry back a negative charge to him; while those which have less than the critical diameter will carry a negative charge off into space. On both counts the corona will be left with a surplus of positive charge. The same arguments hold for the vapors emitted by the nucleus of a comet. Thus comets' tails should consist of negatively charged particles.

Let us follow the career of the particles launched into space. They proceed radially from the sun above the regions of sunspots with rapidly increasing speed, which, however, may be shown to approach a finite limit at a distance of about ten radii from the sun. If they encounter another body, such as the earth, they charge its outer atmosphere negatively, and when this charge reaches a certain value, it will begin to repel them. The oncoming rush will be deflected, and stream past the earth on each side in hyperbolic orbits. Far out in space they must sooner or later meet particles from other bodies, and, if by collision or aggregation they increase beyond the critical diameter, they will first lose speed and then drift back with ever increasing velocity past the earth, directly towards the sun. The space immediately behind the earth would be screened by her, and so be void of particles. Could we take our stand on the moon, we should thus see the earth attended by a faint double tail with a dark dividing line (so conspicuous a feature in comets), immediately behind it, pointing from the sun; and a similar, though perhaps fainter, tail, pointing towards him. Not only so, but the earth helps to form her own tail. For when

the negative charge in the upper atmosphere is high enough, discharges are brought about by the powerful ultra-violet radiation from the sun, and particles are driven off radially from the earth on the side turned towards the sun, only to be drifted back with the other streams into the tail. The effect will be as if a sheaf of light projected from her towards the sun.

Compare with this the description of the Zodiacal Light (Newcomb, 'Popular Astronomy,' p. 416):

> This object consists of a very soft faint column of light, which may be seen rising from the western horizon after twilight on any clear winter or spring evening; it may also be seen rising from the eastern horizon just before daybreak in the summer or autumn. It really extends out on each side of the sun, and lies nearly in the plane of the ecliptic. . . Near the equator, where the ecliptic always rises high above the horizon, the light can be seen about equally well all the year round. . . It is due to a lens-shaped appendage of some sort surrounding the sun, and extending out a little beyond the earth's orbit.
>
> The nature of the substance from which this light emanates is entirely unknown. . . Professor Wright of Yale College finds its spectrum to be continuous. Accepting this, we should be led to the conclusion that the phenomenon in question is due to reflected sunlight, probably from an *immense cloud of meteorites*, filling up the space between the earth and the sun.

The difficulty in this view is that the orbits of such swarms of meteorites as are known to us are distributed irregularly with regard to the ecliptic. On the other hand, Arrhenius' streams of particles, when near enough to be visible, necessarily lie in or near the ecliptic, as required by observation. More than this, the particles emitted by the earth herself should be most abundant over those regions which have been exposed for many hours to the sun. Now it has been observed that the zodiacal light is stronger on what Arrhenius calls the 'evening side' of the earth (*i. e.*, that side which is in the act of turning away from the sun, and has the sun in the west) than on the 'morning side.'

Even at night, when the sun is below the horizon, faint reflections should reach us from the streamers behind the earth, and by an effect of perspective, these should have a maximum in the *point opposite to the sun*, where they will appear most dense. Let Professor Newcomb describe the Gegenschein:

> Another mysterious phenomenon associated with the zodiacal light is known by its German appellation, the Gegenschein. It is said that in that point of the heavens directly opposite the sun there is an elliptical patch of light, a few degrees in extent, of such extreme faintness that it can be seen only by the most sensitive eyes, under the best conditions, and through the clearest atmosphere. This phenomenon seems so difficult to account for that its existence is sometimes doubted; yet the testimony in its favor is difficult to set aside.

How is it that the moon does not exhibit such tails? The moon has

no atmosphere, so that the particles which reach her give up their negative charge to her directly, and it spreads equally all over her surface. When in turn she herself discharges the particles, it will be uniformly in all directions, and she should appear surrounded with a uniform sheath. Possibly this sheath of cosmical dust affords the reason that in a lunar eclipse the shadow of the earth can be traced a short distance beyond the limb of the moon on each side.

The Aurora Borealis.

Perhaps the most interesting application of Arrhenius' theory is his explanation of the Aurora. In a well-known experiment the streams of negative particles forming kathode rays in a Crookes tube are exposed to a magnetic field, when they are seen to describe helices round the lines of force. If the field is powerful enough, they may thus be bent into a complete circle inside a moderately large tube.

Now the negative particles discharged from the sun arrive most thickly over the equatorial regions of the earth, which are most directly exposed to him. Long before they reach any atmosphere dense enough to excite luminescence, they are caught by the lines of force of the earth's magnetic field, which are horizontal over the equator, and have to follow them, winding round them in helices whose radii are so much less than their height above us that the effect to a beholder on the earth is as if they moved *along* the lines of force. Over the equator there is little luminescence, for lack of atmosphere. But as the lines of force travel north and south, they dip downwards making for the magnetic poles, over which they stand vertical. Soon the particles find themselves in lower layers of the atmosphere, comparable in density with our highest artificial vacua, and begin to give out the darting and shifting lights of the kathode ray. But this can only be at the cost of absorption, and by the time the denser layers of air are reached, their energy is exhausted. Hence the dark circles round the magnetic poles from which, as from behind a curtain, the leaping pillars of the Aurora rise. From this point of view it is significant that Dr. Adam Paulsen, who has made a special study of the northern lights, found so many points of correspondence between them and kathode rays that in 1894 he was led to regard the aurora as a special case of the latter, though unable to give any account of their origin in the upper atmosphere, such as is supplied by Arrhenius' theory.

The most obvious test to which we can subject such a theory is to ask from it some explanation of the very remarkable periodic variations in the frequency of auroræ. If they are caused by streams of particles ejected from the sun, there should be some connection between the changes in the sun's activity, as indicated by the number of sunspots, and the number of auroræ observed. Again, since a negative charge

in motion is (pace M. Cremieux) equivalent to a negative current, the passage of electrified particles through the upper atmosphere should affect magnetic instruments on the earth. Sunspots, auroræ, magnetic storms should therefore vary together.

It has long been known empirically that they do agree in a general way. Arrhenius' discussion of the mass of statistics of observed auroræ forms so striking an example of the 'Method of Concomitant Variations' that at the risk of wearying the reader we shall give it in some detail.

1. *Slow secular periods.*

(a) Both sunspots and auroræ show marked maxima at the middle of the eighteenth and the end of the nineteenth centuries.

(b) Sunspots, auroræ, and magnetic storms go through a simultaneous increase and decrease in the well-known period of 11.1 years.

The source of these slow variations must be looked for in the little understood variations of the sun's activity.

2. *Annual period.*

The number of auroræ is greatest in March and September, and least in June and December; and the mean frequency for both hemispheres is somewhat less in June than in December.

Now the sun's activity, as indicated by the number of sunspots, is a minimum at his equator, the spots occurring principally in belts about 15° north and south of his equator. Since the streams of particles issue radially from the sun, the earth will be most exposed to them, when she is most nearly opposite the active belts. But the earth stands opposite the sun's equator on June 4 and December 6, and is at her farthest north and south of it (7°), *i. e.*, most nearly opposite the sunspot belts, on March 5 and on September 3. Moreover, she is somewhat nearer to the sun in December than in June.

As between the two hemispheres, the same conditions apply as those which regulate the seasons, viz., altitude of the sun above the horizon, and length of time during which he remains above it daily. Auroræ should therefore be more frequent in summer than in winter, a result which is verified by the records. And just as the highest daily temperature occurs from two to three hours after mid-day, so we ought to find a daily maximum of auroræ about 3 p. m. It is not possible to verify this directly, since auroræ are not visible in daylight. But Arrhenius remarks (1) that the majority of them occur before midnight and not after it, which is so far in general agreement with the theory; (2) that Carlheim-Gyllenskiöld, discussing the observations made at Cape Thordsen in Spitzbergen during the winter of 1882–1883, with a view to correcting the numbers recorded for the effect of daylight in concealing them, deduces a probable maximum for the number actually occurring at 2.40 p. m.

But though we cannot observe auroræ in daylight, we are not without resource, for even when invisible, they give notice of their presence by disturbing the ordinary course of the records photographically taken in our magnetic observatories. In 1899 van Bemmelen discussed the records of such magnetic storms taken in Batavia. He found that they show maxima in March and September, minima in January and June, and a daily maximum at 3 p. m., and minimum at 1 a. m.

3. *Monthly Variations.*

It is only recently (1898) that the collection of statistics of auroræ published by Eckholm and Arrhenius has brought to light two curious monthly variations in their number.

One of these, with a variation of 20% on each side of the mean, depends on the revolution of the moon in her orbit, showing in the northern hemisphere a maximum when the moon is farthest south of the equator, a minimum when she is farthest north; and vice versa for the southern hemisphere.

The explanation appears highly ingenious. It is as follows: The moon, being unprotected by an atmosphere, is charged by the streams of particles that reach her much as the outer layers of our own atmosphere are charged, and therefore, as we have good reason to believe, to a far higher negative potential than is observed at the surface of the earth. If so, she will seriously affect the number of auroræ at any place over which she stands, by lowering the potential gradient, and thus reducing the number of negative discharges in the highest regions of our atmosphere.

The other variation of some 10% each way has a period of 25.93 days and affects both hemispheres alike. At first sight it is natural to refer this to the synodical time of revolution of the sun on his axis as determined by observations of sunspots. But this is 27.3 days. Remembering that the earth never departs more than 7° from the sun's equator, we should rather take the time of revolution of the equatorial belt for comparison. As estimated by the motion of the faculæ, this is 26.06 days, the equator moving faster than the sunspot belts, and probably the time of revolution of the outermost layers, from which the particles stream, is yet a little shorter. The agreement with the period of the aurora (25.93 days) would thus be within the limits of error of the observations.

Atmospheric Electricity.

Let us now trace the effect of the auroræ on the earth's atmosphere. If they are really kathode rays on a grand scale, they must ionize the air, the negative ions will form centers for condensation, and sinking to the earth by gravitation, will charge it negatively, leaving the layers

at moderate heights positively charged. This agrees with the results of recent observations made from balloons up to heights of 3,000 meters.

Since condensation will depend on the number of ions available for nuclei, we have at once an explanation of the curious fact that cloud-formation in the upper atmosphere is more copious in years of frequent auroræ than when they occur rarely. In this connection another odd coincidence may be mentioned. When sunspots are numerous, Jupiter shines with a white light; when they are few, his light has a reddish tinge. Now it is agreed that Jupiter is still at a high temperature. If, therefore, sunspots cause auroræ on Jupiter, and consequent cloud-formation, we must see less of the heated interior in sunspot years than we do when his cloud-layers are not so opaque.

In 1899 von Bezold showed that the daily variation of the compass over the earth's surface could be simply represented as follows. Imagine two points, one in latitude 40° N., and one 40° S., to move round with the sun. Then it is as if the north end of the compass needle were attracted towards the northerly point, and the south end towards the southerly. Remembering that the air immediately above the earth has a positive charge, we see that this effect would follow by Ampère's rule, if the sun's heat caused two air-whirls, one in the northern and one in the southern hemisphere, over the places of highest temperature, the former rotating counter-clockwise, the latter clockwise. Such whirls would result from the sucking in of currents from the slower-moving north latitudes and the faster-moving south latitudes towards the mean latitude of 40°, in the northern hemisphere, and similarly for the southern. If this be the true explanation, then for a given frequency of sunspots, the amplitude of the diurnal variation should increase by the same fraction of itself for all parts of the earth. Thus if A° is the amplitude at a given place in a year of no sunspots, and A its value in a year for which Wolf's number expressing the relative frequency of spots is f, we ought to find $A = A° (1 + af)$. Now the value of the coefficient a comes out .0064 from *whatever part of the world* the observations be taken from which it is calculated.

Meteorites and Nebulæ.

To the man of science this discussion of terrestrial details will probably be the most convincing part of the evidence adduced by Arrhenius for his theory. But it is time to turn from it, and follow, with lagging imagination, the destinies of those particles, by far the greatest number, which miss the earth and the planets, and launch forth into interstellar space.

Many of them will meet similar streams ejected from other suns,

and overcoming the mutual repulsion of their negative charges by their mighty velocities, will clash together, like Lucretius' atoms, and unite to form larger masses. But this aggregation must have an end. For if, in the void of space, they are unable to get rid of their electric charges, the potential of the growing mass must rapidly increase, since the charge increases as the cube of the radius, being proportional to the total number of particles, while the capacity for holding electricity only increases as the radius itself. To put this in popular language, each particle brings to the account the whole charge it can bear on its surface; but in the mass, since electricity flies to the surface, only the outer parts of those particles which are actually in the surface can be useful in harboring the accumulating charge, and hence the electric pressure rises. When it becomes intense enough to prevent fresh particles from approaching, accretion will cease. Space will thus be sown with masses of moderate size, formed irregularly, particle by particle, in spite of repulsive forces. These are the meteorites which blaze for a moment in the upper air, or in rare cases reach the earth to puzzle philosophers with their porous structure.

Another multitude of the particles will at last reach other suns. For if in their wanderings they have united with others till they are beyond the critical size, they will be drawn in, and raise the charge of the bodies they reach, till they in turn discharge their streams into space.

In these we see the 'greyhounds' of the abyss, engaged in distributing the materials of the universe, forever busied in a cosmic traffic by whose exchanges the stellar hosts are made more and more alike in constitution, whatever may have been their differences in the beginning.

For those myriads which are fated to escape all visible suns, far out in the 'flaming bounds of space' the Nebulæ lie in wait, spreading spider-like their impalpable webs across immeasurable breadths of sky. Ever since the spectroscope showed that many nebulæ are gaseous, and yet shine by their own light, two problems have vexed the astronomers. How can they be hot enough to send light to us, and yet be held together against the expansive force of the heated gas, by the feeble gravitation which such inconceivably diffuse masses can exert at their borders? If they are really at a temperature of not less than 500° C., so as to shine, or, indeed, if they are much above absolute zero, their own gravitation should not be able to prevent their speedy dissipation into space.

Again, why do they show the spectroscopic lines of so few gases, and those the lighter ones, such as hydrogen and helium?

According to Arrhenius the nebulæ are cold, with the cold of empty space. Their light is due to the rain of negatively charged

particles which, plunging into their outermost regions, give rise to electric discharges and make their gases shine as the gases in a vacuum tube. To this the intense cold is no bar, for Stark has shown that the intensity of light excited in a vacuum tube is greater the lower the temperature at which the experiment is tried. And this process should take place at the surface of the nebula, where the lighter gases would be found, the heavier settling inwards. Hence the few lines found in the spectrum of a nebula, and the comparative brightness of the outlying parts, especially to be observed in the planetary and the ring nebulæ.

Such is Arrhenius' theory. It is too early, as yet, to pronounce any judgment upon it, but glancing back over the array of hitherto unexplained facts which fall into order, without forcing, at its touch, we must admit that it is at least plausible. It springs from a single principle, itself a necessary theoretical consequence of the accepted Electromagnetic Theory of light, viz., that light must exert a pressure which, in the case of small particles, may very greatly exceed their weight. By means of this principle in conjunction with recent views about the nature and properties of ions, which can all be experimentally verified, this theory gives a rational explanation of the astounding behavior of comets' tails; accounts for the 'hairy' structure of the corona; shows us how the prominences can float where the existence of a supporting atmosphere is inadmissible; what is the origin of the zodiacal light and the Gegenschein; of 'the certain connection' between sunspots and magnetic storms; of the aurora, and why it is subject to such complicated periodical variations; why meteorites are porous and limited in size; how the nebulæ shine in the absolute cold of interstellar space, and yet hang together; and why their constituents appear to be so restricted, while the suns among which they are strewn give evidence of most of the elements known on earth.

A theory which sweeps the astronomical horizon of so many mysteries must not only arouse our profound interest, but claim the respectful consideration of men of science.

DISCUSSION AND CORRESPONDENCE.

THE NOACHIAN DELUGE.

To the Editor:—My attention has just been called to the inquiries in the August number of the MONTHLY concerning the reply I would make to a number of objections which arise in connection with my theory of the Noachian Deluge. As they are apparently made in good faith I will briefly remark upon them, though it would require a volume fully to discuss the points raised.

1. The question respecting Noah's supposed relation to paleolithic man is answered by saying that it is by no means proved that paleolithic man in Europe and America was not cotemporary with civilized man in Egypt and Babylonia, whose existence is now thrown back in those countries several thousand years before the Christian era. I do not know that there is any evidence that paleolithic man anywhere developed into neolithic man, and so on to a stage of comparative civilization by his own efforts. It seems more likely that he received his new arts by contact with higher races than that he made the inventions of his own accord. Certainly, in America, he did not pass out of the 'stone age,' by himself.

2. With regard to the age of Noah as given in the Scriptures when his surviving children were born it is enough to say that language, like isolated geological facts, has to be interpreted; and it is a fair question whether Noah, here, is not the name of a dynasty, like Pharaoh, or of a family, like Israel. That is to be determined by a thorough study of the literature involved. Israel is indeed the name of a man, but it is constantly used to designate the whole body of his descendants. In so brief an account of a long period of history as we have in the early chapters of Genesis, it would not be strange if much more was compressed into single words than would be done in a fuller history.

3. In reference to the specific statement of facts, it is proper to remark that outside of mathematical and dry scientific treatises, there is little specific statement of facts by anybody. When I read in the papers that the whole town turned out to witness a pageant, I do not expect on inquiry to find that there were no women and children or busy or indifferent men absent, nor do I charge the writer with misrepresenting the facts in making the general statement. But, on the other hand, I take the nature of language into consideration and interpret it to mean simply that there was a great crowd, which had the *appearance* of containing everybody in the town. Again, when I read in a scientific treatise, as I frequently do, that a fact, or explanation of a fact, is 'generally' admitted, I do not charge the writer with either dishonesty or ignorance if it is found that nine tenths of the people of the world have heard neither of the fact nor of the explanation, nor yet if it is found that both the alleged fact and its explanation is disbelieved by a considerable portion of the civilized world. There are few questions on which there is perfect unanimity of judgment, hence if we use the word 'generally' at all, outside of mathematics, we must use it in a modified sense and leave the interpretation to the context.

Applying this well-known principle of interpretation to the case in hand, it is possible to get a pretty definite

conception out of the language both of the Bible and of other confirmatory traditions without being pressed to accept it with mathematical exactness. The single point which I have made is, that, in view of the great instability of geological conditions which accompanied the close of the glacial period, and during which man was in existence, it is unscientific to apply to that period the standards with reference to the rate of elevation and depression of the earth's surface which apply to the present. I have also called attention anew to the unknown, but certainly extensive, destruction of life during the closing stages of the glacial period, and immediately after, in which man may fairly be assumed to have shared to a great extent.

The alleged object of the flood, namely, the destruction of the human race, may then well have been accomplished by submergence limited to central and western Asia, from which I have brought much new evidence going to show that at a very recent geological period, indeed since man's existence, there have been such changes of land level as render it easier than before to credit the existence of a great fact underneath the widespread traditions concerning a deluge in which the last remnants of the human race, except those saved by special arrangement, were destroyed.

G. FREDERICK WRIGHT.

It must be left to readers of the MONTHLY to decide whether or not Professor Wright answers the questions addressed to him by our correspondent. They were as follows:

1. You say, Professor Wright, that "The Paleolithic man of science may well be the Antediluvian man of Genesis." Was Tubal Cain, 'an instructor of every artificer in brass and iron,' an antediluvian man, and, if so, had he not learned to use smoothed stone instruments? Was Noah, himself, a paleolithic or a neolithic man, and did he build the ark with flaked or polished flint implements?

2. You say: "But towards the close of this period there were 120 years (specially mentioned in the Bible as a time of warning) in which the movement was accelerated to such a degree that the rising waters gave point to the preaching of Noah." The period of 120 years here mentioned was deduced from the statement that Noah was 600 years old at the time of the flood. Do you believe that Noah was 600 years old, and that his grandchildren that peopled the earth were subsequently born?

3. You say: "During the last 371 days of this period the catastrophe culminated in the facts specifically related in the Book of Genesis." Do you believe that the 'facts specifically related in the Book of Genesis' are true? For example, that "every living substance was destroyed which was upon the face of the ground, both man, and cattle, and the creeping things, and the fowl of the heaven; and they were destroyed from the earth: and Noah only remained *alive*, and they that *were* with him in the ark."

SCIENTIFIC LITERATURE.

THE STARS.

PROFESSOR NEWCOMB, in the last issue of the 'Science Series' (Putnam), sums up our present knowledge of the stars. The greatest problem which can engage the human mind is the structure and duration of the Universe. This is the problem which the author proposes in the fourteenth chapter, and which he discusses throughout the rest of the volume. The early chapters may be regarded as forming an introduction to this far-reaching investigation. To present a popular statement of the facts of astronomy is no simple task. This the author keenly appreciates, for in the preface he admits that he has failed to satisfy himself. Nevertheless, no one could be better prepared to undertake the work than Professor Newcomb, and the outcome cannot fail to meet with general praise. The author possesses that rare style, which comes from a perfectly clear conception of the subject, and a good command of plain English. He can be exact without the use of technical language.

Among the important subjects, which are discussed in the volume, are the surveys of the stars, which are now in progress. These surveys are of different kinds. There are the cataloguing and numbering of the stars, which are still actively carried on, and by new and novel methods, due to the introduction of photography. To count and fix the positions of the stars is, however, not enough. There must also be photometric surveys, to determine the exact brightness, and other surveys for the systematic study of the spectra, the parallax, and the motions of the stars. There must also be careful surveys of the nebulæ. A most interesting investigation is that of the motion of stars in the line of sight, a study which has reached a wonderful precision at the Lick Observatory, with the great refractor and its spectroscope. This has thrown much light on the subject of double and variable stars. Other subjects of special interest are the great numbers of variable stars, which are found packed into a few dense clusters, and the life history and changes of a star. At present, owing to the incompleteness of the surveys and other studies no entirely satisfactory discussion of the structure of the Universe is possible. The subject, however, is treated in an extremely clear and interesting manner, and all the conclusions are drawn, in regard to the Universe, which the present state of the science permits.

ALASKA.

A NOTABLE book on Alaska has recently left the press of Doubleday, Page & Company (New York) in the form of a report on the Harriman Alaska Expedition of 1900. This expedition was organized by Mr. E. H. Harriman as a means of obtaining definite information concerning the characteristics and resources of the Alaskan coast and interior; and through the cooperation of the Washington Academy of Sciences a strong scientific character was impressed on the work. The personnel included a 'scientific party' of twenty-five specialists, several of them eminent in their respective lines; and every possible facility for original work was afforded these specialists in the course of the voyage and land journeys, so that important records and collections were obtained. The preparation of the material for publication was undertaken largely by members of the Washington Academy, and the papers

have been edited by Dr. C. Hart Merriam, one of the leading contributors to the success of the expedition. The report, as now published, consists of two volumes, but others are promised as remaining material is elaborated. The first volume is largely made up of the narrative of the expedition by the littérateur-naturalist, John Burroughs, and an account of the natives of the Alaska coast region by Dr. George Bird Grinnell. The second volume contains memoirs on the discovery and exploration of Alaska, by Dr. William H. Dall; on Alaskan birds, by Professor Charles Keeler; on the forests of Alaska, by Professor B. E. Fernow; on the geography of Alaska, by Dr. Henry Gannett; on the Alaskan atmosphere, by Professor William H. Brewer; on 'Bogoslof, Our newest volcano,' by Dr. Merriam; on the salmon industry, by Dr. Grinnell, and on fox farming, by M. L. Washburn. Each of these memoirs is a substantial contribution to knowledge of the territory; the whole constitutes a standard source of information concerning Alaska and its resources and possibilities. The volumes are no less notable in form than in substance; they are models of book-making technique. Convenient in form and size, they are sumptuous in effect and finish; typography and paper are irreproachable, the binding is appropriate, and the illustrations are adequate and well distributed. These illustrations are especially fine. There are 39 lithograph plates, showing landscapes, glaciers, flowering and fruiting plants, birds, mammals, etc., with unsurpassed fidelity and refinement; and there are 85 photogravure plates, showing characteristic views of the region with an accuracy and fulness of detail seldom attained and never excelled, some of the pictures of glaciers and bergs, for example, being revelations of the possibilities of photo-mechanical reproduction. These admirable plates are supplemented by 240 text cuts, mainly reproductions of drawings notable alike for faithfulness to nature and for artistic perfection.

SOCIOLOGY.

PROFESSOR GIDDINGS'S new book, 'Inductive Sociology' (The Macmillan Company), is an elaboration of the theories set forth in his previous work on 'The Principles of Sociology.' The present volume covers, however, only one half of the field marked out by the author as general sociology. Its object is, in the author's words, "to present a scheme of inductive method, a somewhat detailed analysis and classification of social facts, and a tentative formulation of the more obvious laws of social activity." Studies of the historical evolution of society and of the deeper problems of causation are deferred for future consideration.

The volume is divided into two books, the first of which deals with social theory, the second with the elements and structure of society. In the first book a new solution is suggested for the puzzling problem of the unit of society. Mr. Giddings maintains that the true unit is neither the individual nor the family but the 'socius.' This introductory book also contains an admirable analysis of the methods of sociology, which is better by far than anything that has been presented since Comte's classification, and is in many respects an improvement upon this earlier attempt. The second book is divided into four parts, dealing respectively with the social population, the social mind, social organization and social welfare. Within each part the material is classified under separate categories, and the special subjects set forth in a series of propositions, distinctions and definitions. To show how sociology can be systematized, a number of statistical tables, formulæ, diagrams and maps are presented; and to encourage further investigation along these lines, blank forms are furnished for the collection and consideration of sociological data.

THE PROGRESS OF SCIENCE.

WINTER MEETINGS OF SCIENTIFIC SOCIETIES.

THE efforts to secure a convocation week for the meetings of scientific and learned societies have met with gratifying success. It may be remembered that a note in a former issue of this magazine called attention to the appointment of a committee of the American Association for the Advancement of Science which secured the cooperation of the Association of American Universities. Most of our leading institutions have now decided to set apart for these meetings the week in which the first of January falls. In some cases no change in the calendar was required, in others it has only been decided that officers may have leave of absence, but in many the Christmas holidays have been lengthened by a few days. The movement has met with practically universal approval, both on the part of institutions of learning and on the part of scientific societies, and represents a gain for science, the importance of which can scarcely be overstated. The advancement and the diffusion of science depend largely on the meetings of our societies. It is of the utmost importance for scientific men to come together and discuss their common interests. Only so can a high and uniform standard be maintained throughout the country, only so will an eager interest in advanced work and research be maintained, only so will men find their proper places and the work they are best able to do, only so will science be adequately recognized and supported by the community. Hitherto the scientific meetings have been divided between summer and winter. The American Association has met in the summer holidays and with it the societies devoted to the physical sciences. In midsummer it is impossible for many to attend the meetings, and those who do suffer great personal inconvenience; the week between Christmas and New Year's Day is too short, breaking into Christmas time and being interrupted by Sunday. This year, for the first time, the week after that in which Christmas falls has been recognized as convocation week, and affords a convenient time for the meetings.

The council of the American Association for the Advancement of Science meets at Chicago on January 1, and the Section of Anthropology of the Association holds a winter meeting at Chicago. The Association will hold a summer meeting at Pittsburgh next year, but will hold a winter meeting in Washington in the following convocation week. The American Society of Naturalists meets at Chicago on December 31 and January 1, in conjunction with the Western Naturalists, and the national societies devoted to morphology, bacteriology, anatomy, physiology and psychology will meet at the same place and on the same days and on the days immediately preceding and following. Other societies meet elsewhere this winter; but it is expected that they will all meet at Washington next year, and that it will be possible hereafter to bring together at least once in three years the great majority of those engaged in scientific work in America.

THE PRESIDENT'S MESSAGE.

PRESIDENT ROOSEVELT'S message to the Congress has been more widely read and more generally approved than any other recent document of this kind.

It contains no platitudes worded in questionable English; it is a vigorous expression of a straightforward and hopeful policy that is American rather than partisan. Such a message should do something towards making obsolete that form of party government which leads one half the people to prevent the other half from doing anything. Even in directions such as the maintenance of the present tariff and the enlargement of the navy, where the president's policy is opposed by a strong minority, it seems that he expresses the general sense of the nation, and in any case the division is not along the inherited party lines.

Apart from the emphasis on efficiency and expertness in all departments of the government which gives the whole message a certain scientific coloring, there are several recommendations that are directly concerned with science and its applications. Three great engineering works are urged—the Isthmian Canal, the Pacific Cable and Irrigation. These enterprises are directly dependent on applied science, and their accomplishment, under the direction of American engineers, will give new opportunities for scientific progress. It appears that we may need to go to Great Britain for the cable, but this ought not to be necessary five years hence. In the case of forestry and irrigation, which are said to be perhaps the most vital internal questions of the United States and are discussed at greater length than any others, the president fully realizes the need of expert and scientific direction. It is recommended that the scientific bureaus concerned with these subjects be united and put under the Department of Agriculture. Concerning this department the president says:

"The Department of Agriculture during the past fifteen years has steadily broadened its work on economic lines, and has accomplished results of real value in upbuilding domestic and foreign trade. It has gone into new fields until it is now in touch with all sections of our country and with two of the island groups that have lately come under our jurisdiction, whose people must look to agriculture as a livelihood. It is searching the world for grains, grasses, fruits and vegetables especially fitted for introduction into localities in the several states and territories where they may add materially to our resources. By scientific attention to soil survey and possible new crops, to breeding of new varieties of plants, to experimental shipments, to animal industry and applied chemistry, very practical aid has been given our farming and stock-growing interests. The products of the farm have taken an unprecedented place in our export trade during the year that has just closed."

The president recommends the creation of a cabinet officer, to be known as secretary of commerce and industries. He calls attention to the important work of the Smithsonian Institution and the needs of the National Museum. He emphasizes the value of the 'National Library,' and advocates a permanent census bureau 'for the sake of good administration, sound economy and the advancement of science.'

THE NAVAL OBSERVATORY.

THE President does not refer in his message to the U. S. Naval Observatory, but he doubtless approves the recommendations in the report of Secretary Long, which, if carried into effect by the Congress, will remove the difficulties which have so long interfered with the scientific work of our national observatory. Secretary Long says:

"Attention is called to the first and very important report of the board of visitors to the Naval Observatory. I earnestly commend its recommendations to careful consideration. This board was created by act of Congress in March last. I believe its visitations will be found valuable in making the

observatory efficient and in rank with the best institutions of the land. It appears that no other observatory in the world has the expenditure of so much money, but also that its results are not commensurate with those of some other observatories the expenditures of which are less. Its head should of course be the best astronomer, who has proper administrative qualifications, that can be found in the country. It is especially desirable that he should have continuity of tenure, as the observatory has undoubtedly suffered from frequent changes in its superintendents.

"While the average term of service of superintendents at Greenwich has been twenty-eight years and at Harvard fifteen, at the Naval Observatory it has been only a little over three. I urgently recommend that the legislation of the last Congress to the effect 'that the superintendent of the Naval Observatory shall be, until further legislation by Congress, a line officer of the navy of a rank not below that of captain,' be repealed, and that on the contrary it be enacted that there shall be no limitation upon the field from which the superintendent is to be selected. As well might the above-quoted statute have provided that the commissioner of fish and fisheries should be selected from the line of the marine corps, or the director of the Geological Survey from the line of the army.

"There is no vital relation between the navy and the observatory. It may happen that some naval officer is pre-eminently qualified for such a place, in which case he would be appointed to it, but the country is entitled to have unlimited range of selection. The present limitation, which shuts out the whole body of civilian astronomers and even any astronomer in the navy who does not happen to be in the line, or, if in the line, below the rank of captain, is peculiar. Only a very small proportion of naval officers are not below the rank of captain, and as most of them are required for naval services —a requirement which is now increasing—the list from which selection can be made is a noticeably small one. It is evident, too, from the wording of the above quotation from the statute, that Congress in passing it had in mind further legislation in this respect."

WORK OF THE DEPARTMENT OF AGRICULTURE.

THE report of the Secretary of Agriculture for the past year shows that progress has been made in strengthening the organization of the National Department of Agriculture, and in increasing the breadth and efficiency of its scientific work. Four bureaus have been organized for the purpose of bringing together more closely the allied lines of work and providing for the expansion which has been authorized by Congress in other lines. These are the Bureaus of Plant Industry, of Soils, of Forestry and of Chemistry. The Bureau of Plant Industry, the creation of which has involved the most reorganization of any of the new bureaus, combines under one head the work in nine different branches, each presided over by an expert, and with a corps of more than two hundred efficient workers. The unification of work and the closer cooperation which have resulted, together with the economy of time in administration, lead the secretary to recommend a further extension of the bureau system in the department. He announces that preliminary plans have been procured for a new agricultural building, providing facilities for bringing together all the administrative and laboratory work in the various lines under one roof.

The report shows that the department has been alert in its efforts to extend the markets for our agricultural products abroad, and no less so in seeking to bring about the production in this country and its new possessions of a large part of the $400,000,000 worth

of products which are at present imported. One half of this now comes from such climates as prevail in Hawaii, Porto Rico and the Philippine Islands, and the secretary declares that 'it is the privilege and duty of the department of agriculture to teach the people of those islands to produce what we now buy from tropical countries.' The establishment of experiment stations in Hawaii and Porto Rico during the year was an important step in that direction. Both these stations have been placed in charge of men sent out from the department, which has also furnished the chief of the new Bureau of Agriculture for the Philippines, established under the War Department in October. An experiment station for the Philippines, to work in cooperation with the new bureau, is strongly recommended. The efficient and valuable work of the experiment stations all over the country is becoming more apparent every year, and a broader, deeper foundation of scientific inquiry is being laid. Cooperation between the department and the stations has greatly increased, so as to meet the varied national and local needs of agriculture and extend the benefits of agricultural investigation to every part of the Union. This cooperation is taking a variety of forms, such as experiments to find grasses, forage crops and cereal grains better adapted to particular localities; experiments in range renovation and management, which are sorely needed in some sections of the West; studies of the water requirements of crops in the irrigated region and of the problems of water conservation and management; soil studies; sugar-beet production; plant-breeding experiments, and studies on the food of man, its preparation and use. In the recent development of the department's work, forestry, soil studies and irrigation have assumed places of prominence. The forestry work, besides the investigations in that subject, deals with the preparation of working plans for the management of forests. Applications for such plans covering over 52 million acres are now on file, a number being from large lumbering companies. The soil survey is being carried on in different parts of the country, and numerous fundamental problems are studied in the laboratories. A new feature of this work will be in the field of soil climatology, a field which is practically new to science. The irrigation studies have not been confined to the arid western states, but have been continued on a more extensive plan in the humid climates, such as Louisiana, Missouri, Wisconsin and New Jersey, indicating that 'irrigation is to have a wide field of usefulness in many sections where it is not a necessity.' The secretary expresses himself at length on the subject of national aid for irrigation, holding that public aid will be necessary in the construction of certain irrigation works, and that reservoirs located in the channels of running streams should be public works, but he holds that the first step toward national aid should be the passage of enlightened codes of water laws by the states to be benefited. In the various other lines of research—in studies of plant diseases and insect pests, the origination or discovery of plants more resistant to disease or climate, the fermentation of tobacco, and the preparation and application of serums and toxins for combating animal diseases—the same spirit of progress has characterized the work as in previous years, and results of much practical as well as scientific importance are announced.

THE NEW STAR IN PERSEUS.

No more striking astronomical discovery has been made in recent years than that of the moving nebulous masses around Nova Persei. That remarkable star, now apparently a gaseous nebula, is still of about the sixth magnitude. Flammarion, An-

toniadi and others, found on photographs of the star a halo, which did not appear about other stars on the same plate, and which was thought to be nebulous. Later it was shown by Professor Max Wolf that this aureole was instrumental, and due to the fact that the Nova was rich in rays for which the lenses were uncorrected. At the same time Wolf found that the Nova was surrounded by a faint nebulosity. Long exposures with the powerful reflecting telescopes of the Yerkes and Lick Observatories showed well this nebulosity, and, especially, nebulous patches at considerable distances from the Nova. From later photographs it was announced from the Lick Observatory and confirmed at the Yerkes Observatory, that these nebulous masses are moving away from the Nova. This is a discovery of the highest importance, having a direct relation to the theory of new stars. The motion of the nebula is very great, amounting to about 1′ of arc in six weeks. Carried backward this motion would bring the nebulous masses at the Nova, when the outburst occurred, a fact of much interest. What this rate of movement represents in miles per second cannot be assumed safely until the star's parallax is known. This has not yet been determined. Our nearest neighbor among the stars, so far as known, has a parallax of less than 1″. A parallax as great as 1″ would indicate a velocity of something like 1,500 miles per second. Either the Nova is very near us, or else the velocity of the Nebula is almost inconceivably great. Indeed, if the parallax should prove to be too small for measurement, the fact would imply a velocity so great that it might be better explained as a motion of light, rather than of matter. The motion, moreover, appears not to be radial, but spiral. The broadening of the lines of the spectrum of the Nova furnishes a clue to the rapidity of motion, the value of which is, however, very doubtful. No definite conclusions can be safely drawn until more data are obtained, and a satisfactory determination of the parallax is given. Meanwhile the astronomical world is watching the developments with the keenest interest. Incidentally the investigation is furnishing a powerful argument for a more extended use of large reflecting telescopes. It may be, that the Golden Age of the refracting telescope has passed!

THE MAGNITUDE AND THE MASS OF THE VISIBLE UNIVERSE.

An interesting question which often occurs to the astronomer and the physicist is that of the magnitude and the material contents of the visible universe. While science is unable at present to give a decisive answer to this question it is nevertheless competent to correlate the observed facts to such an extent that a possible, if not a probable, answer is already attainable. The latest contribution to this subject is due to the indefatigable labors of Lord Kelvin. In the 'Philosophical Magazine' for August, 1901, he attacks the question from the dynamical side in an article 'On ether and gravitational matter through infinite space'; and at the September meeting of the British Association for the Advancement of Science he amplified his investigation in a paper on 'The absolute amount of gravitational matter in any large volume of interstellar space.'

The data for Kelvin's investigation are as follows: The part of the universe visible to us may be considered to lie within a sphere having a radius equal to the distance of a star whose parallax is one thousandth of a second of arc. This distance is about thirty thousand million million kilometres; a distance so great that light would require about three thousand years to traverse it. The number of stars, luminous and non-luminous, within this sphere, Kelvin estimates to be something like one thousand million. This agrees well with the figures of

Newcomb and Young who have estimated that the visible stars are fifty to one hundred millions in number. Assuming the average mass of these stars to be equal to the mass of our sun, the amount of mass in the visible universe is about 2×10^{33} metric tons.

Now, if these thousand million suns had been uniformly distributed within the sphere in question, and had started from rest twenty-five million years ago, they would have acquired under the law of gravitation about such velocities as the stars are now observed to possess; or, if thousands of millions of years ago they started from rest at mutual distances asunder, very great in comparison with the radius of the supposed sphere, and so distributed that they would now be temporarily equally spaced in that sphere, their mean velocities would be of the same order as that actually observed. A non-uniform initial distribution of the suns would give higher velocities for the stars than the observed values; and any great increase in the assumed number of suns would require far greater velocities than the observed values. Hence Kelvin infers that the amount of mass in our universe is greater than one hundred million times and less than two thousand million times our sun's mass.

That there would be plenty of room for a thousand million suns in the assumed sphere is shown by a striking calculation made by Kelvin. Thus, if the suns were placed severally at the centers of the thousand million cubes into which their enclosing sphere may be supposed to be divided, then each sun would be nearly fifty million million kilometres from each of its six nearest neighbors. This distance is a little greater than the distance of the nearest fixed stars from our solar system.

SCIENTIFIC ITEMS.

THE great Nobel prizes, each of the value of about $40,000, have now been awarded for the first time as follows: In Medicine to Professor Behring, in physics to Professor Röntgen, in chemistry to Professor van't Hoff. The prize for the promotion of peace has been divided between Dr. Dumant and M. Passy, and the prize in literature has been awarded to M. Prudhomme.

THE Copley Medal of the Royal Society has been awarded to Professor J. Willard Gibbs, of Yale University.—Director W. W. Campbell, of the Lick Observatory, has been elected an associate member of the Royal Astronomical Society.—Professor F. Lamson-Scribner, of the United States Department of Agriculture, has been given charge of the Bureau of Agriculture established in the Philippines.

THE most important scientific news of the month is Mr. Carnegie's offer of $10,000,000 to endow a national university or institution for scientific research at Washington. The national government hesitates to accept the bonds of the United States Steel Corporation offered by Mr. Carnegie, but this is a detail which will doubtless be arranged.—On the same day that Mr. Carnegie's gift became known, it was announced that Mrs. Stanford had signed the final papers transferring property, estimated at $30,000,000, to Leland Stanford Junior University. It appears that the endowment of Stanford is now about equal to the combined endowment of our three richest universities—Harvard, Columbia and Chicago.